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CONTENTS

The Level of Soil Fertility and Its Relation to Plant and Animal Production, R. J. Webb, J. M. Lewis, W. G. Kammlade, R. F. Fuelleman and T. S. Hamilton 159

Measuring the Nutritive Content of a Foraging Sheep's Diet Under Range Conditions, C. Wayne Cook, Lorin E. Harris and L. A. Stoddart 170

Effects of Some Environmental Factors on Yearling Traits of Columbia and Targhee Rams, Clair E. Terrill, G. M. Sidwell and L. N. Hazel 181

The Effect of Chlorobutanol on Plasma Ascorbic Acid Levels and Semen Production in Sheep, R. W. Colby, C. E. Lindley, E. J. Warwick and T. J. Cunha 191

Ram Semen Production and Characteristics as Influenced by Administration of Thyroprotein, E. J. Warwick, Charles E. Childs, A. E. Flower and W. E. Ham 198

Absorption and Elimination of Thiouracil in Ruminants, Ray E. Ely, Kenneth J. Olson and E. P. Reineke 208

Effect of Feeding Thiouracil to Swine on the Rate of Gain and Weight of the Thyroid Gland, Ramon Acevedo, B. S. Schweigert, P. B. Pearson and F. I. Dahlberg 214

Vitamin A, Vitamin C and Niacin Levels in the Blood of Swine, R. H. Grummer, C. K. Whitehair, G. Bohstedt and P. H. Phillips 222

Relationship of Tryptophane to Nicotinic Acid in the Feeding of Growing Pigs, W. C. Powick, N. R. Ellis and C. N. Dale 228

Genetical Researches on the Number of Vertebrae in the Pig, S. Berge 233

Cobalt Toxicity in Calves Resulting From High Oral Administration, Ray E. Ely, K. M. Dunn and C. F. Huffman 239

The Fertility of Bovine Spermatozoa Treated with Immune Sera for the Control of Trichomoniasis, Banner Bill Morgan 247

A Self-Serving Sprinkling Device for Cooling Dairy Cattle, D. M. Sheath and G. D. Miller 251

News and Notes 257

Contents of previous issues of the JOURNAL OF ANIMAL SCIENCE are indexed in the Agricultural Index which is available in most libraries, and in the November issue of each complete volume of the JOURNAL.

THE LEVEL OF SOIL FERTILITY AND ITS RELATION TO PLANT AND ANIMAL PRODUCTION

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NUTRIENT deficiencies in the rations of farm animals have been the subject of many investigations. Certain elements that are deficient in soils may lead to deficiencies in plants and to abnormal conditions in animals fed on them. Comprehensive investigations involving the relationships of soils, plants, and animals are being given attention in some areas, and it seems that such work may be of greater importance as the deterioration of soil fertility proceeds due to long and continuous cropping and to the effects of soil erosion.

That such possibilities exist was supported to a limited extent at the Illinois Station by Wright (1941) in the response of lambs when trace elements were added to the ration. More recently Pope *et al.* (1947) submitted evidence of a deficiency area in northeastern Wisconsin. Deficiencies of trace elements have been reported in several other areas. Aphosphorosis in cattle and sheep, due to a lack of phosphorus in the soil or to the failure of plants to contain sufficient phosphorus for these animals' needs, has been reported extensively. It is possible that in areas where pasture is low in phosphorus and protein content such deficiencies may be limiting factors in growth and production of cattle and sheep. Hart and Miller (1937) suggest that dietary essentials may be lacking in some of the feeds eaten by sheep in California and that these deficiencies may be related to reproductive efficiency and account at least partially for the usual 80 to 90 percent rather than 100 percent lamb crop. A summary statement of possible nutrient deficiencies is contained in a Report of the Committee on Animal Nutrition of the National Research Council (1945). Russell (1944) described the relationship of some deficiencies and excesses of minerals to animal health.

A review of research on the effects of soil amendments on the composition of plants shows that the composition may be altered by the application of various fertilizers but the extent and character of the changes vary greatly and are related to many factors other than the quantity of the fertilizing material applied. These findings were summarized by Beeson (1941).

Under practical conditions the detection of nutrient deficiencies as related to soil fertility and to the composition of plants growing in any area

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is likely to be complicated because of the difficulities of avoiding the effects of factors other than nutritional. Extending the length of the experimental period is one means of avoiding errors in this respect. Another difficulty arises because of variations in the amounts of vegetation due to lack of rainfall or other climatic conditions. Insufficiency of feed, even though normal in composition, may of course reduce the animal's intake of nutrients below the minimal requirement and thus produce some deficiency symptoms.

Purpose

Because the soils in the Ozark uplift section of southern Illinois are relatively low in fertility and there have been severe soil losses because of erosion, there is an opinion current that nutrient deficiencies exist. This paper presents the results of four years of field experimentation on some lands of the University of Illinois, Dixon Springs Experiment Station, in Pope County in southeastern Illinois. The purpose of the work was to learn whether soil deficiencies of such nature as to interfere with the general health and reproduction of sheep existed and to study the effect of applications of calcium and phosphate upon the vegetation and the animals. Lack of personnel and other conditions prevalent during the war period interfered with some aspects of the work.

Methods and Materials

Six ten-acre fields which had been farmed for many years were used in the experiment. The fields varied somewhat in topography, but all were essentially of the same type of soil and may be described as "strongly weathered, rolling, silt loam timber soils. Because of lack of adequate information no definite soil correlation can be made but they are similar to Clement, Ava and Bluford silt loams."[2] Fields 1 and 2 were left untreated; fields 3 and 4 had applications of four tons of limestone and of 400 pounds of superphosphate per acre; and, fields 5 and 6 had received 4 tons of limestone and 300 pounds of superphosphate per acre. Thirty-six percent superphosphate was applied at 200 pounds per acre in 1937 and 100 pounds per acre in 1940 to all four of these fields when previously used in a forage production experiment. One hundred pounds per acre of 63 percent superphosphate were applied in 1940 at the start of this work on fields 3 and 4.

The plan called for breeding ewes to be fed during the winter on hay cut from one field and to be grazed on a field of similar fertility during other seasons, with alternate use of each pair of fields in succeeding years. Included in the data to be obtained were weights of the ewes, lambing percentages, lamb weights, serum phosphorus, bone ash, some soil analyses, botanical

[2] C. W. Odell, University of Illinois, Soil Survey.

and chemical composition of the vegetation, forage yields, and carrying capacities of the pastures.

Results and Discussion

Determinations of replaceable potassium and adsorbed phosphorus were made in 1941 and of nitrogen, phosphorus, potassium, and of pH in 1943. The results of these determinations are shown in tables 1 and 2.

TABLE 1. REPLACEABLE POTASSIUM AND ADSORBED PHOSPHORUS IN POUNDS PER ACRE, OCTOBER, 1941

Items compared	Field number—					
	1	2	3	4	5	6
Replaceable potassium	300	270	300	300	250	300
Adsorbed phosphorus	42	36	126	106	46	40

TABLE 2. NITROGEN, PHOSPHORUS, AND POTASSIUM IN SEVEN-INCH PLOW LAYER PER ACRE; AND SOIL pH AT TWO-INCH AND FOUR-INCH DEPTHS IN 1943

Field No.	Soil depth, inches	pH	Pounds per acre of		
			N	P	K
1	2	4.2	2,560	30	200
	4	4.4	2,040	18	110
2	2	4.2	2,480	34	160
	4	4.3	2,080	14	90
3	2	6.2	2,720	30	220
	4	5.6	2,330	22	170
4	2	5.8	3,160	42	180
	4	5.6	2,760	26	120
5	2	6.0	2,730	26	210
	4	5.6	2,440	28	160
6	2	6.3	2,800	42	240
	4	5.9	2,360	26	140

These particular analyses were made because potassium and phosphorus are low in parts of southern Illinois. The data however show ample amounts of potassium in all fields for good plant growth. While the earlier records of fertilization of fields 5 and 6 show phosphate applications, the analyses in table 1 fail to show proportionately more adsorbed phosphorus present there than in the untreated fields 1 and 2. This may be due to an error in the early records or to the failure of the test to reveal all phosphorus present.

The determinations made in 1943 and presented in table 2 show the differences in the pH and the more favorable conditions for some species of plants in the treated compared with the untreated fields. Except in the case of nitrogen the data reveal little consistent differences.

Forage and Hay Data

When the test was begun the same kinds and amounts of grass and legume seeds were sown per acre on all six fields even though it was known that the soil conditions were so unfavorable on the untreated fields as to prevent growth of some of the species. On the untreated fields the only le-

TABLE 3. BOTANICAL ANALYSES OF VEGETATION ON EXPERIMENTAL FIELDS FOR FOUR YEARS

Field	Treatment	Species	Percentages for year				
			1942	1943	1944	1945	Average
1	None	Desirable	26.0	—	5.3	23.0	18.1
		Undesirable	74.0	—	94.7	77.0	81.9
2	None	Desirable	36.8	32.3	—	36.0	35.0
		Undesirable	63.2	67.7	—	64.0	65.0
3	L, sP, P	Desirable	44.1	—	27.9	57.0	43.0
		Undesirable	55.9	—	72.1	43.0	57.0
4	L, sP, P	Desirable	63.1	53.1	—	70.0	62.1
		Undesirable	36.9	46.9	—	30.0	37.9
5	L, P	Desirable	65.8	—	51.6	61.0	62.8
		Undesirable	34.2	—	48.4	39.0	37.2
6	L, P	Desirable	71.9	49.2	—	49.0	56.7
		Undesirable	28.1	50.8	—	51.0	43.3

gume that grew was Korean lespedeza in a sparse stand and the stands of grasses were much poorer than on the treated fields. These differences in botanical composition are summarized in table 3. Species listed as desirable included Korean lespedeza, alfalfa, sweet clover, redtop, timothy, Kentucky bluegrass, and Canada bluegrass. Undesirable species included besides common weeds, Panicum, spp., crabgrass, foxtail, slender rush, and broomsedge. Ground without vegetative cover was included in the percentages shown for undesirable species. There was a great improvement in the percentages of desirable species in the treated compared with the untreated fields.

The differences in species as shown in table 3 are important in considering the forage yields from the various fields shown in table 4. Analyses were incomplete in 1943. The extreme lack of desirable vegetation shown for field 1 in 1944 was due to the lack of rainfall, and hence there was a tendency for the sheep to eat any desirable vegetation especially close. Under pasture conditions, a drought may be less unfavorable to the plants having low palatability than to the most desirable plants. Such an effect seemed evident in 1944 and 1945. The drought condition was also reflected in the low forage yields shown for 1944.

TABLE 4. HAY AND FORAGE YIELDS, IN POUNDS OF OVEN DRY FORAGE PER ACRE

Field	Grazing yields				Hay yields	
	1942	1943	1944	1945	1942	1943
1	3,718	—[a]	2,180	4,069	—[b]	3,386
2	—[a]	3,951	2,411	5,695	2,074	—[b]
3	6,492	—[a]	1,961	4,732	—[b]	3,143
4	—[a]	6,096	1,772	5,362	3,307	—[b]
5	6,458	—[a]	2,541	4,882	—[b]	3,761
6	—[a]	4,623	1,744	6,288	2,987	—[b]

[a] Cut for hay.
[b] Grazed.

Monthly precipitation for the grazing seasons of the four years of the experiment is shown in table 5. The lack of rainfall in 1944 reduced forage growth so that it was necessary to graze all of the fields in 1944 and 1945. During the winter of 1944–45 the sheep were fed from other than the experimental fields.

The data in table 6 relating to plant composition are incomplete and show considerable variation. A substantial amount of variation would be expected in such composite samples where the percentage of any one specie of plant

TABLE 5. MONTHLY PRECIPITATION IN INCHES FOR GRAZING SEASONS OF 1942–1945 INCLUSIVE

Years	Inches of rainfall, by months						
	April	May	June	July	Aug.	Sept.	Oct.
1942	6.41	3.90	5.77	3.35	7.63	1.65	2.13
1943	4.33	11.32	2.72	5.80	1.57	3.49	1.83
1944	5.71	3.96	0.81	0.87	2.02	1.38	0.67
1945	8.13	4.57	10.17	2.82	5.81	11.24	1.73

contained in the sample would vary. It is doubtful if there is any accurate method of determining the composition of the feed consumed under pasture conditions for there is no way of ascertaining the percentage of each plant specie eaten. Nevertheless assuming the sheep ate a composite sample, it is apparent that those animals grazing the treated fields usually had a higher protein diet than those on the untreated fields. This may have been due as much or more to the change in plant species as to the change in the composition of any one specie.

The analyses of the composite samples show no consistent improvement in calcium content due to the application of limestone, but there was some increase in the phosphorus content.

Animal Data

Carrying Capacity. The application of limestone and superphosphate to four of the fields increased the carrying capacity of these fields compared with that of the untreated fields. Hence the number of animals was adjusted to the amount of forage anticipated as a result of fertilization. On the untreated fields the pasture was stocked at the rate of one ewe and her lamb or lambs per acre. On the treated fields the rate of stocking was three ewes and their lambs per acre. During winter all sheep were given a similar amount of feed per head. Because of the drought in 1944 the rate of stocking for that year and for 1945 was reduced by one-half. During those years both similarly treated fields were used as pasture for the same lot of sheep and no hay was made for winter feeding.

Individual ewe and lamb gains were not obtained as they are seemingly of little significance in an experiment of this nature, although it is admitted that lack of nutrients may be shown in the failure of animals to gain. Healthfulness may however exist without an increase in weight. Differences in gains are not exact indications of differences in mineral content of forages.

Gains per Acre. The gains in weight per acre of pasture are shown in table 7 and include both ewes and lambs. There was a great reduction in gain

TABLE 6. PERCENTAGE OF PROTEIN, CALCIUM, AND PHOSPHORUS IN COMPOSITE PASTURE SAMPLES AT VARIOUS PERIODS

Dates of sampling[1]	Soil treatments and field numbers					
	None		Limestone and superphosphate (heavy)		Limestone and superphosphate (light)	
	1	2	3	4	5	6
			Protein			
April 25, 1942	10.50	—	19.63	—	12.13	—
May 22, 1942	8.63	—	15.63	—	7.00	—
August 11, 1942	9.94	—	14.63	—	15.75	—
July 24, 1943	—	7.95	—	10.61	—	15.39
April 24, 1944	—	8.72	15.30	16.02	16.30	16.30
May 30, 1944	11.18	10.69	17.21	14.24	15.18	10.08
April 23, 1945	—	11.95	—	13.20	12.70	12.25
June 4, 1945	7.77	9.97	8.74	12.45	12.09	12.55
Average	9.60	9.86	15.19	13.30	13.02	13.31
			Calcium			
April 25, 1942	0.476	—	0.923	—	0.588	—
May 22, 1942	0.581	—	1.047	—	0.465	—
August 11, 1942	1.251	—	1.246	—	1.199	—
July 24, 1943	—	0.821	—	0.371	—	0.860
April 24, 1944	—	0.505	0.550	—	0.789	0.780
May 30, 1944	—	0.326	0.665	0.527	0.508	0.373
April 23, 1945	—	0.490	—	0.548	0.418	0.339
June 4, 1945	0.387	0.497	0.470	0.340	0.476	0.402
Average	0.674	0.528	0.817	0.446	0.635	0.551
			Phosphorus			
April 25, 1942	0.175	—	0.404	—	0.257	—
May 22, 1942	0.195	—	0.298	—	0.203	—
August 11, 1942	0.171	—	0.277	—	0.229	—
July 24, 1943	—	0.153	—	0.195	—	0.229
April 24, 1944	—	0.144	0.317	0.370	0.191	0.191
May 30, 1944	—	0.238	—	0.453	0.316	0.350
April 23, 1945	—	0.263	—	0.368	0.284	0.325
June 4, 1945	0.227	0.280	0.232	0.369	0.349	0.352
Average	0.192	0.218	0.306	0.351	0.261	0.289

[1] The dates are approximate but all samples were taken either on the dates shown or within three days of that time.

per acre in 1944 and 1945 because of the need of using twice as much area per sheep as in the preceding years. The larger number of sheep per acre on the fertilized compared with the untreated fields with the same gain per animal would account for much of the difference in gain per acre.

TABLE 7. POUNDS GAIN PER ACRE OF PASTURE BY EWES AND LAMBS

Fields	Pounds of gain per acre, by years			
	1942	1943	1944[b]	1945[b]
1	56	—[a]	54	26.5
2	—[a]	48.5		
3	129	—[a]	89	97.0
4	—[a]	130.0		
5	152	—[a]	141	78.5
6	—[a]	135.0		

[a] Cut for hay for winter feed
[b] Average for two fields.

Serum Phosphorus. Beginning in January, 1943, and continuing through July, 1945, six ewes in each lot were selected for the purpose of following the serum phosphorus changes. The ewes were identified by numbered ear labels; and, except where deaths made it impossible, the blood was drawn from the same ewes each period. The data are summarized in table 8 where the averages of the serum phosphorus values and their standard errors are shown. The ewes were not receiving feed from the experimental areas in January, 1945.

A statistical analysis of these data showed that while there were signifi-

TABLE 8. SERUM PHOSPHORUS IN BLOOD

Date of sampling	Averages with standard errors in mgm. P per 100 cc. for 6 ewes, by fields		
	Fields 1 & 2	Fields 3 & 4	Fields 5 & 6
January 15, 1943	6.24± .24	6.00± .30	6.40± .68
June 30, 1943	6.67± .23	6.73± .34	6.62± .21
January 27, 1944	6.33± .27	5.42± .43	6.25± .37
August 31, 1944	7.45± .30	7.15± .32	7.50± .76
January 5, 1945	6.33± .28	5.65± .51	6.87± .45
July 10, 1945	7.12± .08	6.70± .40	7.05± .36

cant differences between the two lowest averages (for ewes in fields 3 and 4 on January 27, 1944, and January 5, 1945) and the two highest values (for ewes in fields 1 and 2 on August 31, 1944, and for those ewes in fields 5 and 6 on August 31, 1944) there were no significant differences traceable to: field treatments, season, or year.

Bone Analyses. A few ewe lambs were kept to replace any ewes which died. In all cases these ewe lambs were kept in the lot where produced. All other lambs produced were slaughtered. Each year the bone of the left fore leg—knee to ankle—of five lambs from each lot was obtained for ash determinations. These lambs never received any feeds except those produced on the experimental fields. The results of the analyses are shown in table 9. No analyses are shown for 1943 as the bones were discarded in the analytical laboratory because of a misunderstanding. The ash is on a fat-free basis.

TABLE 9. AVERAGE PERCENTAGES OF BONE ASH OF LAMBS

Fields	Percentages, by years		
	1942	1944	1945
1 & 2	53.77	63.34	64.82
3 & 4	53.06	64.54	66.09
5 & 6	53.76	64.06	66.02

There was little difference in the average percentages between lots, and the differences lack significance but the data show a consistently larger average percentage in the case of the lambs raised on the treated fields. A large difference between 1942 analyses and those for 1944 and 1945 will be noted. A fairly severe infestation of internal parasites developed in all lots in 1942. The greatly increased percentages of bone ash in all lots in the other years was apparently due to the control of such infestations through the use of phenothiazine. It is apparent that an infestation in one lot and not in others might lead to a serious misinterpretation of the data.

Discussion of Results

Changes in botanical composition and in yields of forage resulted from the applications of limestone and phosphate. There was no positive evidence of any significant change in the chemical composition of some of the plants of the same species because of these applications. However, the data secured were not of a character to answer this question with definiteness; but, there may be less change in nutrient content under some conditions than under others. A report by Beeson *et al.* (1945) pertaining to different levels of superphosphate and lime fertilization for Ladino clover stated "marked responses

in yield were obtained at two locations from phosphorus and lime treatments. The Ca, P, and N contents of the crop were only slightly affected by even the extreme treatments used." Ladino clover was not present in any of the fields in the present study, but it may be possible for the time to assume that legumes which were present would show a similar although probably not exactly the same response.

Beeson and others[3] in a preliminary report gave information on sudan grass grown on a light-textured, phosphorus deficient soil. Potash and nitrogen were applied to the entire field and superphosphate in addition to one-half the area. The report states that the superphosphate fertilized plot yielded a significantly larger quantity of hay than did the no phosphate plot. A test of the feeding value of the two hays was made using lambs as the test animals. A paired feeding trial was conducted and was followed by digestion trials. No difference was observed in the growth of the lambs, and there was no significant difference in the digestibility of the hay. An additional experiment with field peas yielded similar results.

It has been assumed that the uptake of minerals by a plant is governed primarily by the mineral content of the soil in which the plant grows. The results of many investigations on this subject indicate that the problem is much more complex than this. In addition to the availability of the particular mineral in the soil, the presence of other mineral elements, the physical characteristics of the soil, the available water supply, the temperature, amount of sunlight, the length of the growing period, and the state of maturation are factors influencing the uptake of the mineral element and of its distribution in the plant. In general, a particular plant variety tends toward a characteristic form and chemical composition when grown under optimum conditions. It has been noted, also that the chemical composition of the reproductive parts of a plant are less affected by suboptimal conditions than are its vegetative parts. Within the seeds, the embryos are still less susceptible to variations than are the endosperms. In general, members of the legume family are more constant in chemical composition than are members of the grass family. Many factors have some effect on the composition of a plant, but the mineral content of the soil is at times one of the less important. Thus improvement in soil fertility may have a much greater effect upon plant growth through increased yield than through changes in plant composition. A plant is not a repository for the greatest amount of material available about its roots.

It follows, then, that the major result of differences in soil fertility, so far as the ability of the soil to furnish feed for livestock is concerned, may be

[3] Contained in A Summary of Five Years of Activity as presented to the 1945 Collaborators' Meeting, Regional Nutrition Laboratory, Ithaca, New York.

the amount of growth or other animal product produced per unit of land area rather than any marked or measurable effect upon the composition of the gains of the animal or upon other animal products produced. Since no discernible deficiencies became apparent the results of the experiment here reported are in agreement with these statements. This is not to say that the use of soil amendments does not affect the composition of plants but such effects as were obtained in this study did not show in the bone ash or serum phosphate or reproductive performance of the experimental animals.

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MEASURING THE NUTRITIVE CONTENT OF A FORAGING SHEEP'S DIET UNDER RANGE CONDITIONS[1]

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EACH year approximately 31 million sheep graze the ranges of the West. These ranges—nearly 75 percent of the total area of the West—furnish forage for these animals the major portion of each year. Because of scarce summer rainfall and frequent droughts, the nutritive value of the range forage is often borderline, yet sheep ordinarily receive no supplement.

Obviously it is vital to understand the nutritional assets and defects of these ranges, for maintenance of both the ranges and the western sheep population. As yet, however, little is known about the actual composition of the sheep diet. The reasons for this lack of information are twofold.

First, western range vegetation is highly variable. The mountain lands present highly divergent soil depths; local accumulations of alkali; favorable and unfavorable growing conditions existing side by side, as on north and south facing slopes, and high seasonal variations in growth conditions. The resultant variability of plant-growth rate and environmental conditions brings about a correspondingly variable chemical composition. Together with the difficulty of knowing just what parts of plants are actually eaten by the grazing sheep, this chemical variance has for years made the problem of making representative collections of range forage for chemical analysis one of bewildering difficulty.

Second, lack of nutritional information on western range forage is intensified by the very numbers of plant species to be found on these ranges. There are thousands, so that determining those which compose the grazing sheep's diet is impossible except by minute scientific observation. For instance, it is not uncommon for as many as 50 plants to be important constituents of the diet, no one of them making up more than perhaps 8 percent of the total forage consumed. The foraging sheep's diet may change materially from day to day depending upon many interrelated factors. Sheep prefer certain species to others and further, they select certain portions of the plants in different plant associations. The preference and amount consumed may vary with soil, site, vegetation type, plant composition, season, and intensity of grazing.

Most attempts to study range diets have considered only the major forage

[1] This investigation was supported in part by a grant from Swift and Company.
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plants and the chemists have analyzed only the parts thought to be consumed. In predicting the animal's diet, only rough estimates comparing utilization or consumption among different species accompanied the chemical analyses of the range plants. Attempts have been made to determine the diet by multiplying species composition of the flora by the percentage of each species which has been consumed at the end of the season (Esplin *et al.*, 1937). The obvious necessity for generalization in this method has prevented it from becoming a satisfactory basis for scientific study. An attempt to measure diet by analysis of the plant species contained in the stomach has also proved unsatisfactory (Norris, 1943).

The method presented in this paper is an entirely new approach to this problem. It is based upon chemical analysis of the vegetation before being grazed as compared to chemical analysis after being grazed. The 'before and after' method has been used in determining percent utilization of range plants (Cassady, 1941; and Stapledon *et al.*, 1927) but it has not been used in measuring the grazing animal's diet or in measuring chemical composition of ingested material.

Description of the Method

Briefly, this method of determining the sheep's diet consists of collecting a given number of specific plant 'units' before grazing and a similar number after grazing. Each plant species is sampled both before and after grazing and each sample is weighed and chemically analyzed. The difference in weight and chemical composition between the before-grazing sample and the after-grazing sample serves as a measure of the nutrient content of the ingested forage.

The plant 'unit' which is collected is an easily definable and recognizable portion of the individual plant. It varies with the plant species but may be a single leaf, a single stem, or even an entire plant. It is selected for each species for uniformity and with a view of making it easily recognized so that any field man can collect 'units' of any species readily. Also, it must be large enough so as never to be entirely consumed by a grazing animal, because, after-grazing 'units' must be collected to determine what percent has been removed by the sheep.

The unit in the case of most browse plants can be confined to twigs of current year's growth (figure 1), for bunch grasses, the entire clump; for semi-bunch grasses, only the individual stem (figure 2); for sod grasses, one sixteenth of a square foot or individual tiller stems; for annuals and most forbs, either the entire plant or an individual stem (figure 3); and for some coarse broad-leafed forbs, only the leaf and leaf stem.

To overcome bias in selecting individual 'units' in harvesting a sample

Figure 1. Illustration of a summer-range browse, serviceberry (*Symphoricarpos rotundifolius*), (A) showing an observation, (B) an ungrazed unit, and (C) a grazed unit.

from the range, use is made of what is termed an 'observation.' This may be an entire branch of a shrub or an entire plant of a herbaceous species and may include one or several 'units.' All the 'units' on one 'observation' are included in the sample collected, regardless of the number. The part of the 'observation' not included in the 'units,' such as the woody stem of a shrub, is discarded. Figures 1 to 4 show 'observations' and 'units' of some common western range species and may serve to clarify the use of these terms.

In collecting plant units to measure plant utilization by sheep, sample

Figure 2. Illustration of a summer-range semi-bunch grass, mountain brome grass (*Bromus carinatus*), (A) showing an observation consisting of two ungrazed units, and (B) an observation consisting of two grazed units. Note that leaves only are used by sheep.

areas are randomly located by sampling directly in front of the sheep rather than directing the sheep to selected sampling localities. In each general area, which according to the grazing schedule is to be grazed by the sheep, three 900-foot transects 250 paces apart are located perpendicular to and directly in the path of the foraging animals.

Generally, the day before the grazing animals are to use the area, a defi-

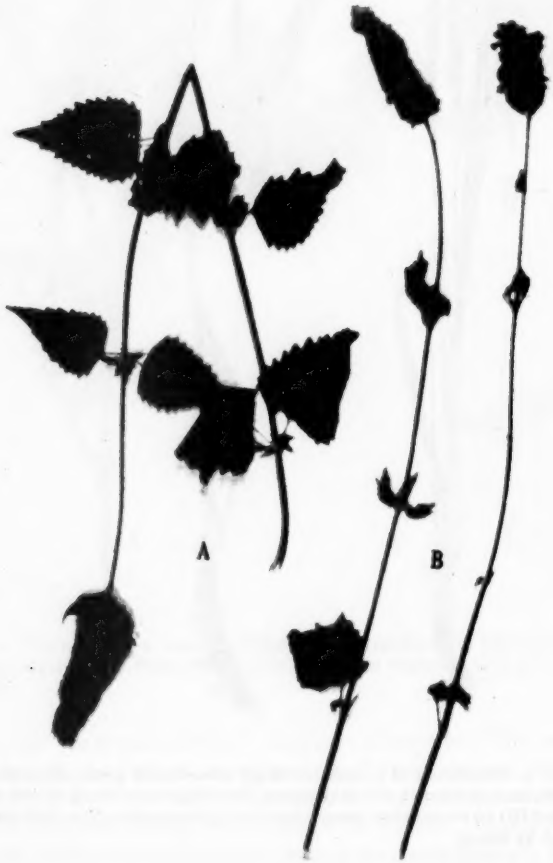

Figure 3. Illustration of a summer range forb, horsemint (*Agastache urticifolia*), (A) showing an ungrazed unit, and (B) two grazed units.

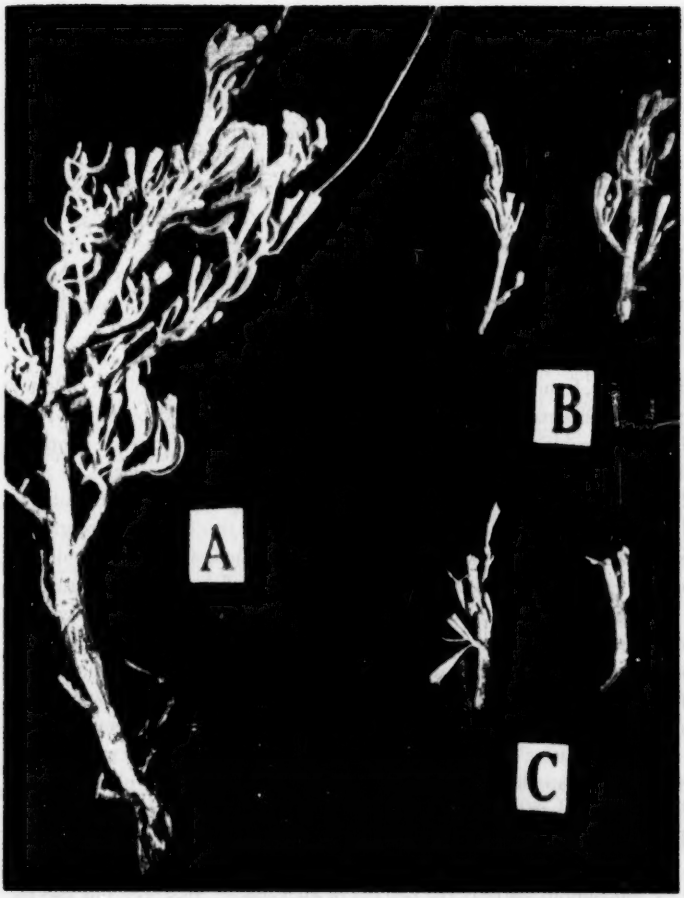

Figure 4. Illustration of a winter-range browse plant, big sagebush (*Artemisia tridentata*), (A) showing an observation. (B) two ungrazed units, and (C) two grazed units.

nite number of plant units are collected along those transects from each important forage species. The number of units collected varies with the species but must be of sufficient quantity to be a statistically reliable index of the average weight of a unit before grazing. This generally requires from 100 to 1400 units depending upon the size and variability of the individual

units. The collector paces along the transect and collects at the end of a given number of paces the 'observation' nearest the tip of the toe on an imaginary line perpendicular to the transect. From this observation, he removes all the units and places them in the collection bag. The number of paces between collections depends upon the number of units needed for a sample and the abundance of the species.

As soon as possible after the animals have grazed the range, samples are collected again along the same transect to determine the average 'unit' weight and the nutrient content of the unused portion of the unit after the plant has been grazed. Procedure is identical to that used in collecting before-grazing samples except that generally a larger number of units must be collected for a statistically reliable sample after grazing.

To calculate the number of units requisite to a composite sample on a given range, from 25 to 75 individual units of each species should be collected and weighed separately; standard deviation may then be determined. From this it is possible to specify the number of units necessary for each sample in order to obtain a mean that will not deviate from the true mean by more than 5 percent—a probability ratio of 19 to 1. The formula for calculating the number of units which should be collected for this degree of accuracy is as follows: $N=(\sigma/.025\overline{X})^2$. N represents the minimum number of units to collect, σ the standard deviation, and $\overline{X}$ the mean of the field or test sample.

By this collection technique, plant material from two or three grazing areas—six to nine transects—may be collected weekly by one man. In addition to calculating the actual diet of the sheep, it is possible to evaluate the effect of such factors as site, soil type, vegetation type, and season of the year, all of which have been found to influence the sheep's dietary habits.

For comparative purposes all samples should be put on a dry matter basis instead of an air dry basis. After collections are made, the plant material should be dried, weighed to determine average weight per unit, and analyzed chemically to determine nutritive value.

To determine quantity of each plant in the diet of the sheep, the investigator must know not only the percent of each species consumed but also the quantity of each on the range. To approximate this quantity, a transect of 10 quadrats, each 25 square feet in area, is laid down along the utilization transect and the number of square feet of each species within each plot is determined by the use of a measuring frame one foot wide and five feet long, which is subdivided into squares of 1/16 square foot area. By counting the number of 'units' per square foot area, and multiplying this number by weight per unit previously determined, it is possible to obtain a close approximation of the weight of each plant species per unit of land area.

Application and Discussion of the Method

In tables 1 and 2 are shown examples of data gathered on a typical mountain-range area of northern Utah in the summer of 1946. The calculations show botanical (table 1) and chemical (table 2) composition of the grazing sheep's diet in aspen-type forage September 1. Similar data have been gathered for other vegetation types and at various dates during the grazing season, both on mountainous summer ranges and desert winter ranges, with equal success.

In table 1, column 1, are shown the major plant species composing the range vegetation in terms of percent density or average square feet occurring per 100-square-foot plot. Column 3 shows actual weight of a plant unit as determined in the before-grazing utilization sample. The percent of each species which is consumed (column 6) is obtained by subtracting the dry weight of the after-grazing sample from the dry weight of the before-grazing sample and converting to percent of the before-grazing weight. In order to determine the percent each species contributes to the diet, it is necessary to determine the weight of each species consumed. This is accomplished by multiplying the weight in grams per 100 square feet (column 5) by the percent consumed (column 6) for each species. Column 8 shows the same data expressed in percent of each species included in the sheep's diet.

In table 2, the percent of protein in the portion of plants being consumed

TABLE 1. AN ILLUSTRATION OF THE PLANT SPECIES COMPOSITION OF A SHEEP'S DIET

Column No.	1	2	3	4	5	6	7	8
Name of plant	Avg. density of area[1]	Units per sq. ft. of density	Avg. weight of one unit	2×3 weight per sq. ft. of density	4×1 actual weight per 100 sq. feet	Amount consumed	5×6 total weight consumed	Diet
	Sq. ft.	*No.*	*Gm.*	*Gm.*	*Gm.*	*percent*	*Gm.*	*percent*
Serviceberry	1.42	210.7	.322	67.85	96.35	43.5	41.9	10.64
Sweet anise	2.17	17.0	1.310	22.27	48.33	37.2	18.0	4.57
Wild rye	9.08	217.7	.913	198.76	1804.74	0.0	0.0	0.00
Mountain brome	2.42	217.7	1.197	260.59	630.63	21.2	133.7	33.96
Meadow rue	0.67	43.9	.903	39.64	26.56	55.0	14.6	3.71
Aspen peavine	8.00	49.8	.833	41.48	331.84	46.8	155.3	39.47
Western chokecherry	0.67	141.2	.582	82.18	55.06	54.7	30.1	7.65

[1] Traces and unimportant plant species made up an additional 1.5 percent density and were not of sufficient forage value to sample.

TABLE 2. CHEMICAL ANALYSIS OF A SHEEP'S DIET

Name of plant	Composition of diet by species	Protein in part consumed	Calcium in part consumed	Phosphorus in part consumed
	percent	*percent*	*percent*	*percent*
Serviceberry	10.64	10.90	2.32	0.623
Sweet anise	4.57	8.31	1.98	0.312
Wild rye	0.00	0.00	0.00	0.000
Mountain brome	33.96	3.04	0.40	0.247
Meadow rue	3.71	7.55	2.25	0.494
Aspen peavine	39.47	13.30	1.42	0.299
Western chokecherry	7.65	8.12	3.03	0.667
Weighted Avg. percent	—	8.72	1.35	0.352

is calculated by multiplying the dry weight on the before-grazing sample by the percent protein in that sample to determine protein yield. In the same way, the dry weight of the after-grazing sample is multiplied by its percent protein.

The protein yield of the after-grazing sample is then subtracted from the protein yield of the before-grazing sample to give actual amount of protein consumed. This difference is divided by total herbage weight consumed (weight of before-grazing sample minus weight of after-grazing sample) to give actual percent of protein in the diet.

The percent of each nutrient in each species is weighted according to the percent of the diet which that species contributes, to obtain a weighted average percent of each nutrient in the diet. Thus, on this range, the forage consumed by sheep actually contained 8.72 percent protein, 1.35 percent calcium, and 0.352 percent phosphorus.

It has been found that sheep are much more selective in their diet than ordinarily thought, as has been previously pointed out by Stapledon *et al.* (1927). Actually, they consume largely leaves and tender stem tips and reject the tougher and more fibrous parts of the plant. This means a much better quality of forage actually makes up the diet than ordinary chemical analyses would suggest.

For instance, a sample of current-years-growth of shrubs is collected as usual and found to have 10 percent protein. This is equivalent to the before-grazing sample as collected by this method, but actually it may be far below the protein content of the animal's diet. Therefore, another sample is collected after grazing and is found to have only 5 percent protein. If the before-grazing sample weighed 1000 grams, it contained 100 grams of protein. If the after-grazing sample weighed 500 grams (utilization 50%), it contained

only 25 grams of protein. Therefore, the 500 grams actually consumed by the sheep contained 75 grams of protein or 15 percent. In all cases, this method has shown the diet to be of much higher quality than have previous studies on the same range. The data presented in table 3 illustrate by an actual field test that the common method of analyzing summer range plants, i.e., analysis of the entire grazable portion of the plant without adequate allowance for selection of different portions, underestimates the amount of protein actually consumed by the sheep. The difference in the two methods of analysis is great in every case.

The new method has some disadvantages because it is usable only with herded sheep and because it is more time consuming and expensive since it involves two collections and two chemical analyses. Its accuracy, however, appears to well justify its use where conditions permit.

Summary

Need for an understanding of the nutrition problems on the western range is of paramount importance. Despite the importance of this problem, little is known as to the actual composition of the grazing animal's diet. The reasons for this lack of knowledge are many fold, including (a) difficulty of collecting representative samples of vegetation because of soil, site, and seasonal variations, (b) difficulty of finding what species and portions of plants actually are consumed, and (c) difficulty in interpreting the nutritive content of the ingested forage.

TABLE 3. AVERAGE PERCENT OF THE ENTIRE PROTEIN PRODUCED WHICH IS INGESTED BY GRAZING SHEEP OVER THE ENTIRE SUMMER GRAZING SEASON FOR THREE SELECTED PLANT SPECIES AS MEASURED BY TWO METHODS OF ANALYSIS

Plant	Snowberry (*Symphoricarpos rotundifolius*)	Mountain brome (*Bromus carinatus*)	Groundsel (*Senecio serra*)
	percent	*percent*	*percent*
Total protein produced×percent utilization of the species	27.5	18.0	32.7
Protein difference when calculated before grazing and again after grazing	35.2	25.7	65.3

The method here presented for determining the nutritive content of the sheep's diet under range conditions is an entirely new approach to this problem and is based upon chemical analyses of the vegetation before being grazed as compared to chemical analyses after being grazed. Briefly, the meth-

od consists of collecting a predetermined number of plant units before grazing and a similar number after grazing. Each plant species is sampled both before and after grazing and each sample is weighed and chemically analyzed. The difference in weight and chemical composition between the before-grazing sample and the after-grazing sample serves as a measure of the nutrient content of the ingested forage.

It was found from this study that sheep are highly selective in their diet and consume largely leaves and tender stems, rejecting the more fibrous parts of the plant. Consequently, a much better quality of forage actually makes up the diet than chemical analyses of bulk samples would indicate.

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EFFECTS OF SOME ENVIRONMENTAL FACTORS ON YEARLING TRAITS OF COLUMBIA AND TARGHEE RAMS

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SELECTION of stud rams is the most important operation in the improvement of sheep through breeding. When selections are based on production records it is essential to know the effect of measurable environmental factors on these records in order to make maximum improvement. The effect of these nongenetic factors may then be minimized before selections are made.

Yearling rams have been studied separately from yearling ewes (Terrill, Sidwell and Hazel, 1947) because the methods of handling rams is different from that for ewes from weaning age on. Ram lambs ordinarily receive more grain and better pasture than ewe lambs and are handled in a smaller band. Furthermore, a lower proportion of rams are retained to yearling age than ewes.

The purpose of this study was to determine the importance of age of dam, type of birth, year of birth, age at shearing, and inbreeding on yearling traits of Columbia and Targhee rams. The traits studied were grease fleece weight, clean fleece weight, staple length, body weight, body type, condition (degree of fatness), face covering and neck folds. Breed differences in these traits were also observed.

Data and Methods

The data used in this study were taken on 359 Columbia and 213 Targhee yearling rams born during the years 1941 through 1945. Some previous selection had been practiced since from 15 to 68 percent of ram lambs weaned were available for study at yearling age. The numbers and percentages of rams retained to yearling age for breeds and years are shown in table 1. Rams included in the first 2 years were also studied as weanlings (Hazel & Terrill, 1946a).

Staple length was measured and scores for face covering were taken just prior to shearing by a committee of three men working independently. Fleeces were weighed on the shearing floor and body weights were taken immediately after shearing. Clean fleece weights were estimated from the clean yields of small side samples (about 35 grams) and grease fleece weights.

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TABLE 1. NUMBER AND PERCENTAGES OF RAMS RETAINED TO YEARLING AGE

Breed	Year of birth	No. ram lambs weaned	No. rams studied as yearlings	Percent yearling rams of rams weaned
Columbia	1941	109	41	37.6
	1942	135	20	14.8
	1943	128	43	33.6
	1944	177	121	68.4
	1945	210	134	63.8
	Total	759	359	47.3
Targhee	1941	85	50	56.8
	1942	99	21	21.2
	1943	96	39	40.6
	1944	113	55	48.7
	1945	132	48	36.4
	Total	525	213	40.6

Scores for body type, condition and neck folds were taken by a committee of three men a few days after shearing. The scoring system was the same for the four traits evaluated by scoring; rams with highest merit being given a score of 1 and those with lowest merit a score of 5. Fifteen possible scoring units were obtained by assigning plus or minus values where merit appeared to be slightly above or below the whole unit.

The analysis was carried out as suggested by Yates (1934) for multiple classification tables with unequal numbers, except that the method was extended according to the least squares procedure to include age at shearing and percent inbreeding as independent variables (Hazel, 1946). The age at shearing, which averaged 404 days for Columbia and 403 days for Targhee rams, was used in the analysis as the age at which each of the traits was measured. The coefficient of inbreeding ranged from 0 to 34.6 percent with averages of 9.9 percent for Columbias and 10.7 percent for Targhees. Classifications were made for age of dam (mature and 2-year-old dams), type of birth (singles, twins, and twins raised singly), and year of birth (1941 to 1945 inclusive).

Results and Discussion

The means, standard deviations within classes, differences due to age of dam, type of birth, and year, and the regression of each trait on age at shearing and percent inbreeding are summarized in tables 2 and 3. Many of the differences, although statistically significant, were too small to be im-

TABLE 2. STATISTICS FOR YEARLING TRAITS OF COLUMBIA RAMS

Statistic	Grease fleece weight, (lbs.)	Clean fleece weight,[1] (lbs.)	Staple length, (cms.)	Body weight, (lbs.)	Type score	Condition score	Face covering score	Neck folds score
Mean	12.07	5.43	11.14	125.1	1.89	1.82	2.45	1.31
Standard deviation	1.84	.99	1.28	13.5	.42	.35	.58	.57
Mature minus 2-year-old dam	.92*	.27	−.08	7.9*	−.08	−.04	.001	−.02
Single minus twin	.81	.27	.04	7.1*	−.10	−.10	−.03	−.03
Single minus twin raised singly	.47	.02	.12	4.9*	.06	−.004	−.07	−.02
Deviation from average for year of birth 1941	−.15*	.34*	−.19	1.5*	.19*	.08*	.02*	.13*
1942	2.27*	.62*	−.03	19.3*	−.31*	−.20*	−.21*	−.06*
1943	.74*	.49*	.02	3.3*	.03*	−.03*	.003*	.04*
1944	−.16*	−.47*	.14	− 6.9*	.17*	.13*	−.06*	−.02*
1945	−2.70*	−.98*	.05	−17.2*	−.08*	.03*	.25*	−.08*
Regression on age at shearing	.047	.032*	.0001	.204	−.0003	−.0006	.006	.003
Regression on percent inbreeding	−.013	−.008	−.013	−.324	.008	.004	.0005	−.003

[1] The clean fleece weights were practically free of moisture since the samples were dried in a conditioning oven at 212° F. for 6 hours, whereas clean wool on a commercial basis contains 12 percent moisture.

* Signifies that the statistic is large enough to account for 2 percent or more of the total variation in that trait.

TABLE 3. STATISTICS FOR YEARLING TRAITS OF TARGHEE RAMS

Statistic	Grease fleece weight, (lbs.)	Clean fleece weight,[1] (lbs.)	Staple length, (cms.)	Body weight, (lbs.)	Type score	Condition score	Face covering score	Neck folds score
Mean	10.83	4.82	9.02	117.1	2.08	1.95	4.03	1.39
Standard deviation	1.59	.85	1.20	11.8	.42	.38	.67	.23
Mature minus 2-year-old dam	.36	.25	.15	− .8	.02	−.003	.06	.05
Single minus twin	.62	.36*	.42*	2.7	−.08	−.07	−.26*	−.02
Single minus twin raised singly	.04	.31*	.44*	2.9	−.01	−.03	−.14*	−.01
Deviation from average for year of birth 1941	−.29*	.27*	−.35*	−.5*	.24*	.11*	−.02	.08*
1942	1.40*	.34*	−.11*	8.8*	−.04*	.05*	−.19	.11*
1943	.60*	.37*	.07*	2.3*	.04*	−.02*	.04	.003*
1944	.32*	−.34*	.30*	1.3*	−.06*	−.07*	−.001	−.06*
1945	−2.03*	−.64*	.09*	−11.9*	−.18*	−.07*	.17	−.13*
Regression on age at shearing	.077*	.031*	.023	.466*	−.010	−.006	−.015	.002
Regression on percent inbreeding	−.023	−.025	−.015	−.585*	.016*	.013*	.016*	.0002

[1] The clean fleece weights were practically free of moisture since the samples were dried in a conditioning oven at 212° F. for 6 hours, whereas clean wool on a commercial basis contains 12 percent moisture.

* Signifies that the statistic is large enough to account for 2 percent or more of the total variation in that trait.

TABLE 4. SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF THE YEARLING TRAITS OF COLUMBIA AND TARGHEE RAMS

Source of variation	Degrees of freedom	Grease fleece weight	Clean fleece weight	Staple length	Body weight	Type	Condition	Face covering	Neck folds
		Mean squares							
Columbia Rams									
Total	358	5.96	1.35	1.62	303	.20	.13	.36	.37
Age of dam	1	46.27**	4.06**	.42	3,448**	.31	.08	.00	.02
Type of birth	2	20.52**	2.36	.24	1,621**	.47	.30	.10	.04
Year of birth	4	205.04**	29.85**	.82	8,578**	1.86**	.56**	2.02**	.40
Age at shearing	1	25.55**	11.69**	.00	477	.002	.004	.43	.10
Percent inbreeding	1	2.31	.79	2.25	1,461**	.90*	.28	.00	.13
Within main classes	349	3.38	.99	1.64	183	.17	.12	.34	.33
Percent of total variation accounted for		45	29	2	41	14	7	7	14
Targhee Rams									
Total	212	3.97	.96	1.52	215	.22	.16	.47	.59
Age of dam	1	3.61	1.73	.61	17	.01	.00	.09	.08
Type of birth	2	7.04	2.46*	3.76	167	.12	.09	1.15	.01
Year of birth	4	62.14**	8.49**	2.50	2,038**	1.10**	.26	.48	.35**
Age at shearing	1	40.56**	6.33**	3.51	1,467**	.71*	.28	1.46	.02
Percent inbreeding	1	7.14	8.96**	3.06	4,789**	3.78**	2.48**	3.80**	.00
Within main classes	203	2.54	.72	1.43	140	.18	.15	.44	.05
Percent of total variation accounted for		39	28	10	38	21	14	9	13

* Signifies probability of chance occurrence <.05.
** Signifies probability of chance occurrence <.01.

portant, in that they accounted for relatively small percentages of the total variation. Those large enough to account for two percent or more are designated in tables 2 and 3. The mean squares are shown in table 4, together with the percentages of the total variance in each trait which could be attributed to the combined effects of all the factors studied.

Grease Fleece Weight

Yearly differences were the most important environmental source of variation in grease fleece weights, accounting for 38 and 30 per cent of the total variation in Columbias and Targhees, respectively. Years had a greater effect on grease fleece weight than on any other trait. This was also true of yearling ewes of these breeds (Terrill *et al.*, 1947). The range of average grease fleece weights for the 5 years was 5.0 pounds for Columbias and 3.4 pounds for Targhees.

Grease fleece weight increased with each day's increase in age at shearing on an average of 0.05 and 0.08 pound for Columbias and Targhees, respectively. The average change for each day's increase in age was consistent with that for yearling ewes of 0.06 pound for each breed (Terrill *et al.*, 1947), and also larger than the average daily growth from birth to shearing of about 0.02 to 0.03 pound.

Type of birth accounted for slightly less than 2 percent of the total variation in each breed. The advantage of single lambs over both twins and twins raised singly was greater for Columbias than for Targhees. Type of birth had a less important effect on yearling rams than ewes (Terrill *et al.*, 1947). It is probable that the better care given the rams and the greater intensity of selection reduced the difference between twins and single lambs among the rams.

Age of dam was more important in causing variation in grease fleece weight in Columbias than in Targhees. The advantage of rams having mature dams over those with 2-year-old dams was 0.9 pound for Columbias and 0.4 pound of Targhees. This was consistent with the respective differences of 1.0 and 0.5 pound for yearling ewes (Terrill *et al.*, 1947).

Inbreeding did not have an important effect in either breed, although the average change in grease fleece weight with each one percent increase in inbreeding was greater for Targhees than Columbias which was also true of yearling ewes (Terrill *et al.*, 1947).

The accuracy of selection based on yearling grease fleece weights will be increased by adjusting for years and age at shearing in both breeds and for age of dam in Columbias. The environmental factors studied were more important for grease fleece weight than for any other trait considered, accounting for 45 percent of the total variation in Columbias and 39 percent in Targhees.

Clean Fleece Weight

Variation among years was the most important cause of variation in clean fleece weights, accounting for 25 and 17 percent of the total variation in Columbias and Targhees, respectively. The range of average clean fleece weights for the 5 years was 1.6 pounds for Columbias and 1.0 pounds for Targhees.

An increase of each day in age at shearing resulted in an average increase of 0.03 pound of clean wool in each breed which is more than twice the average daily growth from birth to shearing of about 0.013 pound. Inbreeding and type of birth had greater effects on clean fleece weights of Targhees than of Columbias.

Adjustment of clean fleece weight for years and age at shearing will in-

crease the accuracy of selections based on that trait. The effect of environmental factors on clean fleece weight was less than for grease fleece weight or body weight but greater than for other traits.

Staple Length

None of the environmental factors studied had significant effects on staple length in either breed. Years and type of birth accounted for 3 and 2 percent, respectively, of the total variation in staple length in Targhees. In each breed twins had slightly longer staple than twins raised singly. This has been true in other groups studied (Hazel and Terrill, 1945, 1946a, 1946b; Terrill *et al.*, 1947), and appears to have been due to a more favorable environment for length of staple for twins which were run in a separate band until weaning during 3 of the 5 years.

There would be little loss in accuracy if no adjustment for environmental factors were made for staple length in Columbia and Targhee yearling rams. Staple length was least affected by environmental factors of any traits studied with the exception of face covering in Targhees.

The sex difference of 0.54 cm. for weanling ewe lambs over ram lambs (Hazel and Terrill, 1946a), is reversed by yearling age. Columbia yearling rams excelled ewes by 1.2 cm. and Targhee yearling rams excelled ewes by 0.8 cm. (Terrill *et al.*, 1947). This change may be due to the better management and more intense selection practiced on rams than on ewes after weaning.

Body Weight

Yearly differences were the most important cause of variation in body weight, accounting for 32 per cent of the total variation in Columbias and 18 percent in Targhees. The range in average body weight for the five years was 36.6 pounds for Columbias and 20.8 pounds for Targhees.

Age of dam had an important effect on body weight in Columbias but not in Targhees. This was also true of yearling ewes (Terrill *et al.*, 1947). Yearling ram offspring of mature Columbia ewes averaged 7.9 pounds heavier than those from 2-year-old dams. Type of birth also had a greater effect on body weight in Columbias than in Targhees. Columbia single rams averaged 7.1 pounds heavier than twins and 4.9 pounds heavier than twins raised as singles.

Inbreeding was an important source of variation in Targhees accounting for 11 percent of the total variation. Only 1 percent of the total variation in body weight was accounted for by inbreeding in Columbias but the effect of inbreeding was highly significant. The average decrease in body weight

with each increase of one percent of inbreeding was −0.32 pound for Columbias and −.59 pound for Targhees. These were larger than the regression coefficients of −.030 pound for weanling lambs (Hazel and Terrill, 1946a) and −.06 and −0.39 pound for yearling Columbia and Targhee ewes, respectively (Terrill *et al.*, 1947). One of the most noticeable features of this study was the greater detrimental effect which inbreeding had on Targhees as compared with Columbias. No very good reason for this difference can be advanced; however, it may be pertinent that Columbias were developed from a breed cross contain approximately one-half fine wool breeding while Targhees containing about three-fourths fine wool breeding.

Body weight was significantly related to age at shearing in Targhees but not in Columbias. The regression of body weight on age at shearing was 0.47 pound for Targhees. This was slightly greater than at weaning age (Hazel and Terrill, 1946a) and was greater than the average daily growth from birth to shearing of 0.29 pounds.

Increased accuracy of selection will result from adjusting yearling body weights of Columbia and Targhee rams for years and type of birth, for age of dam in Columbias, and for age at shearing and inbreeding in Targhees. All environmental factors studied had nearly as great an effect on body weight as on grease fleece weight, accounting for 41 and 38 percent of the total variation in Columbias and Targhees, respectively.

Body Type

Body type score was affected most by yearly variation which accounted for 11 and 10 percent of the total variation for Columbias and Targhees, respectively. Age at shearing had a significant effect upon body type score in Targhees but not in Columbias. Neither age of dam nor type of birth had a significant effect upon body type in either breed. Again inbreeding had a greater effect in Targhees, accounting for 8 percent of the total variation in body type score. The regression coefficient of 0.016 was somewhat greater than that of 0.009 for weanling lambs (Hazel and Terrill, 1946a) and that of 0.011 for yearling ewes (Terrill *et al.*, 1947). Body type score should be adjusted for years in both breeds and for inbreeding in Targhees before selections of breeding rams are made.

Condition

Yearly differences accounted for 5 and 3 percent of the total variation in condition score for Columbias and Targhees, respectively. Again the effect of inbreeding was more pronounced in Targhees, accounting for 7 percent of the total variation but its effect was not significant for Columbias. The re-

gression coefficient for condition on inbreeding of .013 for Targhees was somewhat greater than that of 0.007 for weanling lambs (Hazel and Terrill, 1946a) and of 0.006 for yearling ewes (Terrill *et al.*, 1947).

The effects of age of dam, type of birth and age at shearing on condition score were not significant for either breed. Condition score should be adjusted for years in both breeds and for inbreeding in Targhees before selections are made.

Face Covering

Yearly differences in face covering were important for Columbias but not for Targhees. Inbreeding had a significant effect on face covering in Targhees but this was not true at weanling age (Hazel and Terrill, 1946a) or on yearling Targhee ewes (Terrill *et al.*, 1947). None of the other factors studied had any significant effect on face covering. It does not seem essential to make any adjustments on face covering scores for environmental effects.

Neck Folds

The only important environmental source of variation for neck folds was that due to yearly differences. There was an indication of a trend in both breeds toward absence of skin folds. Since selection was being practiced in that direction it is possible that part or all of the yearly variation in neck folds was due to a genetic trend rather than to environmental factors.

Breed Differences

Columbia yearling rams excelled Targhees in each trait studied. This was also true of weanling lambs (Hazel and Terrill, 1946a) and of yearling ewes (Terrill *et al.*, 1947).

Application of Results

Improvement of sheep by selection is often slow because many advantages of the selected sheep are due to environmental factors. These advantages are not inherited and therefore do not result in improvement of the next generation. For example, a Columbia ram from a mature dam and born in 1942 would have 5.9 more pounds of grease wool as a yearling than a Columbia ram from a 2-year-old dam, and born in 1945 if the rams were equal in fleece producing ability. If the actual difference between 2 rams with such environmental effects was 2 pounds of grease wool the latter ram would probably excell in breeding ability for grease fleece weight but he would rarely be selected unless the environmental effects were adequately recognized.

Increased accuracy of selection is the practical result of adjusting for

measurable environmental factors. Thus by adding .92 pound to the yearling grease fleece weight of each Columbia ram born from a two-year-old dam the average environmental advantage of offspring from mature dams can be eliminated. Likewise, the disadvantage of records made in a year when feed conditions were poor can be eliminated by adding the difference between that year and the average of a number of years, to each record obtained in the poor year. Similar adding or subtracting of environmental differences which are important for other traits should be made. Selections based on records so adjusted will lead to greater genetic improvement than selections based on unadjusted records which often sort out animals with the better environmental effects rather than those with greater ability for production.

Summary

The effects of age of dam, type of birth, year of birth, age at shearing and percent inbreeding on grease fleece weight, clean fleece weight, staple length, body weight, type, condition, face covering and neck folds were studied on 359 Columbia and 213 Targhee yearling rams. These rams were born during the years 1941 through 1945.

The effect of environmental factors was greatest on grease fleece weight, body weight and clean fleece weight and least on face covering and staple length. Year of birth was the most important environmental source of variation and age of dam was least important. Age of dam was more important in Columbias while age at shearing was more important in Targhees.

Single rams had heavier bodies and fleeces than twins. Fleece and body weights, staple length, type and condition improved with increasing age at shearing and became poorer with inbreeding. Inbreeding had a greater detrimental effect on body weight, type and condition than on other traits. Inbreeding had a noticeably greater effect on Targhees than on Columbias.

Greater effectiveness of selection is the practical result of adjusting for environmental effects. Accuracy of selection of Columbia and Targhee rams may be increased by adjusting grease fleece weights, clean fleece weights body weight, type and condition for differences between years; grease fleece weight, clean fleece weight and body weight for age at shearing; body weight for type of birth; grease fleece weight and body weight for age of dam in Columbias; and body weight, type and condition for inbreeding in Targhees.

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THE EFFECT OF CHLOROBUTANOL ON PLASMA ASCORBIC ACID LEVELS AND SEMEN PRODUCTION IN SHEEP[1]

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IT HAS been found that the feeding of chlorobutanol to animals of at least certain species causes an increase in blood plasma ascorbic acid levels. Lundquist and Phillips (1944, 1945*a*, 1945*b*), Moore and Cotter (1945), Bortree *et al.* (1941, 1943), and Phillips *et al.* (1941), have shown that the feeding of chlorobutanol to dairy cattle will increase the plasma ascorbic acid levels.

Erb (1947) found that the feeding of chlorobutanol to steers increased the urinary excretion of ascorbic acid but did not increase the blood plasma ascorbic acid levels. Moore and Cotter (1945) fed chlorobutanol to dairy cattle heifers and observed increased urinary excretion of ascorbic acid.

Longnecker *et al.* (1940) found that the feeding of chlorobutanol to rats brought about increased urinary excretion of ascorbic acid. Sutton *et al.* (1942) reported that gonadectomized rats fed chloretone were able to synthesize ascorbic acid. Roy *et al.* (1946) reported that the stimulating effect of chloretone on ascorbic acid excretion of the rat is greatly lessened if the animals are made deficient in either thiamine or riboflavin.

The work reported herein was done for the purposes of (1) determining the effects of feeding various levels of chlorobutanol on blood hemoglobin levels, blood plasma vitamin A and carotene levels, and especially plasma ascorbic acid levels in sheep, and (2) making preliminary observations on the effects of chlorobutanol feeding on libido and semen production and quality of rams.

Experimental Animals

Ten two-year-old Hampshire rams and three intact Hampshire and three spayed Rambouillet ewes were used in these studies. The sheep were fed the regular flock ration consisting of pea vine silage, pea vine hay, barley, oats, wheat bran, dried molasses, beet pulp, corn, linseed oil meal, salt and steamed bone meal. The chlorobutanol was given orally by capsule daily.

Experimental Methods

Blood was collected twice weekly and plasma vitamin C and blood hemoglobin levels were determined. Plasma vitamin A and carotene levels were determined once each week. The vitamin C was determined by the method

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of Mindlin and Butler (1938). Hemoglobin was determined by the method of Evelyn (1936), and vitamin A and carotene determined by the methods of Kimble (1939).

Semen was collected by means of an artificial vagina once each week. Two ejaculations were taken into the same vial as rapidly as the ram would serve and subsequent evaluation was based on the pooled sample. The semen was evaluated for the factors of initial motility, methylene blue reduction time, volume, motility after one hour at 37° C. and density. Density was determined by the method of Comstock *et al.* (1943). Motility was determined by placing a drop of semen in mineral oil on a slide held at 37° C. by a stage warmer and observing under low power of the microscope. It was rated subjectively on a scale from 0 to 5 with 5 representing maximum motility. Methylene blue reduction time was determined by placing 0.1 cc. of semen, 0.3 cc. methylene blue solution, (50 mg. methylene blue per 100 cc. of semen diluter) in 1 cc. of semen diluter (Green, Winters, and Comstock, 1942) and noting the time required to reduce the color of the methylene blue when held at 37° C.

Experimental Results

Experiment I

Ten rams were used in the first experiment. Three rams were fed ½ gram of chlorobutanol[2] daily, three received 1 gram daily, and one ram received 1½ grams daily for the first two weeks. Three untreated rams were used as controls. The dosages were increased to 2, 3 and 4 grams daily respectively for the next two week period. The dosage was then increased to 6, 8 and 10 grams daily, respectively, for one week at which time the experiment was terminated. The 8 and 10 gram levels were found to have an anesthetizing effect. The ram receiving 10 grams and one ram receiving 8 grams became anesthetized after 4 days and chlorobutanol feeding was discontinued. The rams were completely anesthetized for about 48 hours. Recovery was slow. The other rams receiving 8 grams went off feed and became quite weak. No ill effects were observed in the rams receiving 6 grams of chlorobutanol daily.

In the first experiment no appreciable differences were found between the plasma ascorbic acid levels between control and treated rams although there was an upward trend in both groups (figure 1). No apparent differences in the hemoglobin, carotene or vitamin A levels between the various groups could be detected either before or after feeding chlorobutanol.

Semen had been collected weekly from these rams during the year previous to this trial. For unknown reasons some of the experimental rams were

[2] Chlorobutanol used was obtained through the courtesy of Dr. D. F. Green, Merck & Co., Rahway, New Jersey.

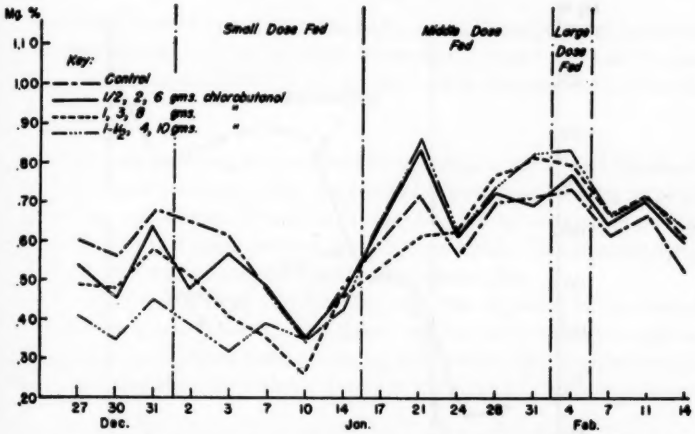

Figure 1. Plasma ascorbic acid levels obtained with the rams fed various levels of chlorobutanol in the first experiment. Note that no differences in plasma ascorbic levels were obtained between treated and control groups. All groups were kept in one pen.

poor semen producers. No apparent improvement in semen quality followed the feeding of chlorobutanol. There were no apparent increases in libido following the feeding of this material. In several cases treated rams failed to serve so semen collection was impossible. Since all rams exhibited an upward trend in plasma ascorbic acid levels with no appreciable differences between treated or control groups, it was wondered if some transfer of effect from treated to control rams could have occurred. During the first experiment the treated and control rams were kept together. Therefore, during a second experiment with rams, the treated and control groups were kept in separate lots.

Experiment II

In this experiment, eight of the same rams used in experiment I were used with four being treated with six grams of chlorobutanol daily while four were kept as controls. A marked increase in the plasma ascorbic acid levels of the treated lot as compared to the controls was observed in this experiment (figure 2). The first apparent difference was noted after nine days of treatment and the difference between the controls and the treated rams continued to increase until the end of the 3 weeks trial. No differences in hemoglobin, vitamin A or carotene levels were noted between the two lots of rams. As in the first experiment no improvements in libido or semen quality were detected in the treated rams. Weekly semen data is given in table 1.

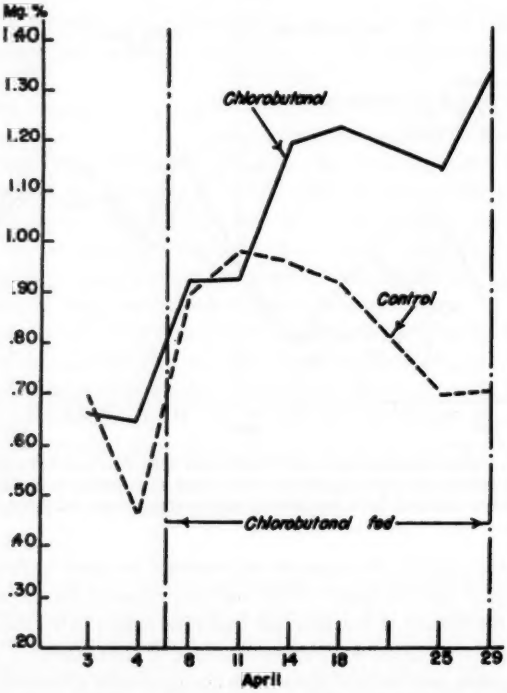

Figure 2. Plasma ascorbic acid levels obtained with control and chlorobutanol treated rams in second experiment when the two groups were kept in separate pens.

TABLE 1. AVERAGES OF ITEMS USED TO EVALUATE SEMEN QUALITY OF CONTROL RAMS AND THOSE FED 6 GRAMS OF CHLOROBUTANOL DAILY. FOUR RAMS IN EACH GROUP

Date	Initial motility		Motility 1 hour at 37° C.		Volume, (cc.)		Methylene blue reduction time, (minutes)		Denaity, (colorimeter readings)*	
	Control	Treated	Control	Treated	Control	Treated	Control	Treated	Control	Treated
4/ 5/47	2.0	3.0	0.50	2.50	0.45	0.75	82.50	64.50	80.50	68.00
4/12/47	3.5	3.67	2.50	2.67	1.07	1.10	63.25	45.33	62.25	70.33
4/19/47	2.5	2.67	1.00	2.67	0.77	1.58	72.75	45.33	63.00	66.00
4/26/47	4.0	1.67	.50	1.67	0.98	1.60	35.50	83.33	64.50	66.00
5/ 2/47	4.5	1.67	0.00	0.00	0.83	1.42	35.50	61.33	58.25	58.00

* Concentration of sperm cells tends to be inversely related (r =about −.75) to colorimeter readings.

Preliminary work was done in the latter part of this experiment in analyzing urine for ascorbic acid excretion. There was at least a four fold increase in the ascorbic acid excreted by the treated rams as compared to the controls.

Experiment III

Three pairs of ewes with one intact Hampshire and one spayed Rambouillet in each pair were used to test the effect of chlorobutanol feeding on blood constituents in the ewe. The chlorobutanol was fed to two pairs of ewes at the rate of 4 and 6 grams per ewe per day, respectively. The ewes receiving chlorobutanol and the controls were kept in separate lots.

An increase in plasma ascorbic acid level was apparent in the treated ewes within 3 days (figure 3). The plasma ascorbic acid level in the ewes remained high in the treated animals during the 3 weeks chlorobutanol was fed and dropped appreciably within 4 days after chlorobutanol was discontinued.

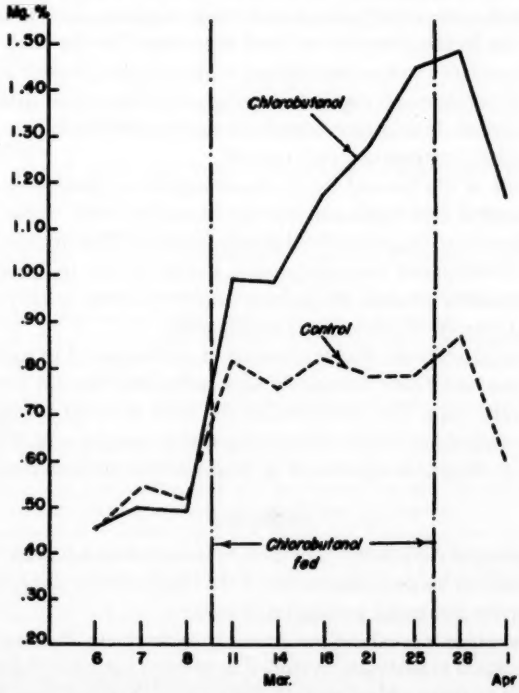

Figure 3. Plasma ascorbic acid levels obtained with control and chlorobutanol treated ewes in the third experiment. The two groups were kept in separate pens.

Both spayed Rambouillet ewes receiving chlorobutanol died within 6 days. The ewes died of a severe enteritis and pneumonia. Death may have been due to a lowering of resistance by the feeding of chlorobutanol or it may have been complicated by spaying. The Hampshire ewes were then continued on the 4 gram level. They showed no apparent ill effects.

No appreciable differences between the treated and the control ewes were noted in blood hemoglobin, carotene, or vitamin A levels.

Discussion

The rapid increase in plasma ascorbic acid levels in the treated ewes indicates that they respond to chlorobutanol feeding in a manner similar to that found by Bortree *et al.* (1943). Lundquist and Phillips (1944, 1945*a*, 1945*b*) in dairy cows.

Bortree *et al.* (1943) found that bulls required larger doses of chlorobutanol than cows to bring about an increase in plasma ascorbic acid levels and that the increase was not so great as in cows. In this work rams fed chlorobutanol failed to show an increase in blood plasma ascorbic acid in one trial and in another trial required a considerably longer time than ewes to show an increase. It thus appears probable that sex differences in response in sheep are similar to those observed in cattle.

The work of Phillips and Lardy (1940) suggests a relationship between plasma ascorbic acid levels and the production of virile sperm in bulls. Scheidenhelm *et al.* (1942) observed greatly increased libido in slow breeding bulls by chlorobutanol treatment over a 3 week period. In this trial there was no noticeable increase in libido or improved semen quality observed following treatment of rams with chlorobutanol.

Erb (1947) has shown that the feeding of chlorobutanol to steers significantly increased urinary elimination of ascorbic acid but did not increase blood ascorbic acid. The rams used in the trials reported herein likewise showed a marked increase in urinary excretion of ascorbic acid. This is similar to the findings of Longnecker *et al.* (1940) in their work with rats.

Summary

The feeding of chlorobutanol to sheep was studied to determine the effect it might have on various constituents of the blood of ewes and rams and on sexual activity and semen production of rams.

The first phase was carried out primarily to determine the proper dosage of chlorobutanol to feed rams. A daily dose of 8 or 10 grams of chlorobutanol produced anesthesia. No harmful effects were observed from feeding 6 grams daily to rams.

In the first experiment when treated and control groups of rams were

kept together, no differences were found in blood plasma ascorbic acid levels between groups. In the second experiment when treated and control groups were kept separate a marked increase was observed in the plasma ascorbic acid levels of rams fed 6 grams of chlorobutanol daily.

In ewes being fed 4 grams chlorobutanol daily, there was an immediate increase in plasma ascorbic acid levels.

In this experiment no differences were noted between treated and untreated animals in hemoglobin, or plasma carotene and vitamin A levels.

There was no increase in libido nor any definite improvement of semen production and quality in the chlorobutanol fed rams.

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RAM SEMEN PRODUCTION AND CHARACTERISTICS AS INFLUENCED BY ADMINISTRATION OF THYROPROTEIN[1]

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DURING the hot summer months in some localities, rams of at least some breeds go through a period of lowered semen quality as indicated by increases in percentages of abnormal sperm, decreased volume, lowered rate of motility, and a decrease in number of spermatozoa (McKenzie and Berliner, 1937; Bogart and Mayer, 1946; and Gunn *et al.*, 1942).

During the three years 1944, 1945, 1946 the highest temperature recorded at Pullman, Washington was 96° F. and the average monthly maximums for July and August varied from 77° F. to 83.6° F. The highest minimum recorded was 67° F. and the average minimum for July and August varied from 52.8° F. to 56.1° F. Under these moderate temperature conditions, semen collections from Hampshire rams during the hottest months in each of these three years showed (unpublished data) that a decrease in semen quality occurred during these months in some rams during some years.

Berliner and Warbritton (1937) noted that thyroidectomized rams produced semen of low quality and that administration of thyroxine to rams during the summer months sometimes resulted in an improvement in semen quality. They therefore suggested that the effect of season on semen production and quality might be indirect and due to a thyroid deficiency. Bogart and Mayer (1946) presented data indicating that the feeding of thyroprotein gives results similar to those observed following injections of thyroxine.

In the work reported here, thyroprotein[2] was administered to rams both during the summer months and during a period in the spring when thyroid secretions would presumably be at a normal level.

Experimental Animals and Procedures

Three different groups of rams were treated with thyroprotein and maintained with untreated control animals on regular flock rations during experimental periods of six or seven weeks. Rams were divided as evenly as possible into experimental and control groups on the basis of semen production during the pre-treatment period. Where both two-year-old and yearling rams were used in an experiment, they were evently distributed among the groups. In addition to semen studies, records were kept of weight changes as

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[2] PROTOMONE kindly supplied by Dr. W. R. Graham of the Cerophyl Corporation, Kansas City, Missouri.

an indication of the activity of the material given. Purebred Hampshire rams were used in all experiments. Thyroprotein was given orally in gelatin capsules.

Weekly semen collections were made with the artificial vagina during the treatment period and during periods of one to three weeks immediately preceding and succeeding the treatment period. Each specimen consisted of two ejaculations taken into the same vial as rapidly as the ram would serve. Subsequent examinations and evaluations were made on the pooled sample of the two ejaculates. Volume was determined by use of a graduated pipette giving measurements accurate to within 0.1 ml.

Motility ratings were determined by observing a drop of undiluted semen in a drop of mineral oil on a slide held at 37° C. by a stage warmer. Motility ratings of 0 to 5 were made under low power of the microscope, 0 indicating no motility and 5 indicating maximum motility.

The method of evaluating the ability of spermatozoa to survive varied somewhat from trial to trial. In the first experiment (summer 1945) samples were held under oil at 42°C, and at 4° C. Those held at 42° C. were observed each 15 minutes until all motility was lost, and those held at 4° C. were observed every two days until no motility was observed. During the second and third trials, semen was held at 37° C. and observed only once, at the end of one hour of storage.

A methylene blue reduction test based on the work of Beck and Salisbury (1943) was devised for ram semen. As used routinely, 0.1 ml. of fresh ram semen was diluted in 1 ml. of sheep semen diluter prepared as recommended by Green, Winters and Comstock (1942), and to this was added 0.3 ml. of a solution of 50 mg. of methylene blue in 100 cc. of the diluter. This suspension was covered with mineral oil to exclude air and incubated in a constant temperature water bath at 42° C. (1945 trial) or 37° C. (both 1946 trials) until the blue solution was reduced to whiteness or until it was apparent that no reduction was going to occur. Tremendous variation was encountered between samples in ability to reduce the methylene blue, many samples making the reduction in from three to five minutes while others failed to reduce the color at all. In actual practice, reductions always occurred in two hours or less or the sample failed to reduce the methylene blue. In order to make comparisons between the averages of all groups possible, a time of 120 minutes has been arbitrarily assigned to samples which did not reduce the color.

The concentration of sperm cells was estimated from a density reading on each specimen of semen made with an Evelyn type colorimeter according to the procedures outlined by Comstock, *et al.* (1943). The authors made a series of comparisons between densities and actual hemocytometer sperm counts

and found them to be negatively correlated (r = about -0.75). The data are reported in colorimeter readings. The averages of our counts for a given colorimeter reading approximate the figures given by Comstock, *et al.* (1943). For example, colorimeter readings of 60 indicated a concentration of about 2,500,000 spermatozoa per cu. mm., while a reading of 70 indicated a concentration of about 1,500,000 spermatozoa per cu. mm.

Experimental Results

First Experiment, Summer 1945

On July 17, 1945, five rams were placed on a treatment of 6 gm. of thyroprotein (iodinated casein containing 3% thyroxine by chemical analysis) daily, and five rams kept as controls. Early in the treatment period, two treated rams lost weight very rapidly, became lethargic, appeared to have increased heart sounds, and gave other symptoms of an over-dose of thyroxine. Their semen also degenerated rapidly in all characteristics measured. Treatment was discontinued on these rams and the data on this semen have been omitted from the tabulation of results (table 1). However, the perform-

TABLE 1. AVERAGES OF CRITERIA USED TO COMPARE SEMEN OF UNTREATED RAMS WITH THAT OF RAMS RECEIVING 6.0 GMS. OF THYROPROTEIN DAILY, SUMMER, 1945

Date	Volume (cc.)		Init. Motility		Dur. Mot. at 42° C. (minutes)		Dur. Mot. at 4° C. (days)		Meth. Blue Reduc. Time (minutes)		Density (colorimeter readings)	
	Untr.*	Tr.**	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.
Pre-Treatment Period												
June 23, '45	1.7	1.9	5.0	5	39.0	30.0	3.2	3.0	7.2	5.2	51.9	54.0
June 30, '45	2.3	1.4	4.8	5	33.0	35.0	11.6	14.0	7.5	20.6	54.6	57.6
July 7, '45	1.7	1.1	5.0	5	15.0	15.0	2.0	2.0	3.3	3.5	—	—
July 14, '45	2.3	1.8	5.0	5	33.0	30.0	16.8	14.0	10.0	9.3	52.4	57.3
Period of Treatment												
July 21, '45	1.8	2.1	4.8	5	21.0	12.5	24.4	17.3	4.9	5.4	53.9	50.3
July 28, '45	2.1	2.2	5.0	5	25.5	20.0	14.8	12.6	5.0	5.1	50.0	53.6
Aug. 4, '45	1.9	2.0	5.0	5	81.0	80.0	14.8	14.6	15.7	3.5	56.2	58.6
Aug. 11, '45	1.9	2.4	4.2	5	84.0	50.0	12.0	15.3	22.7	6.0	57.9	54.6
Aug. 18, '45	2.2	1.9	4.6	5	60.0	35.0	12.8	7.3	6.0	4.3	66.2	64.0
Aug. 25, '45	1.2	2.3	4.2	5	30.0	40.6	15.3	17.3	12.5	7.3	54.8	66.0
Post-Treatment Period												
Sept. 1, '45	1.6	1.8	5.0	5	30.0	18.5	12.0	11.3	5.8	7.1	58.3	59.3

* Untr.—Untreated. Averages for five rams.

** Tr.—Treated. Averages for three rams. This group originally contained five rams, but two had to be discarded because they failed to tolerate the dosage administered.

ance of these two rams must be considered in the over-all picture, since they demonstrate the possible adverse effects of over-doses.

A third treated ram showed such an excessive loss of weight after three weeks that the dosage was reduced to 6 gm. every other day, which he tolerated quite satisfactorily. The other two rams tolerated the daily dosage of 6 gm. throughout the experimental period without undue loss of weight or increases in heart sounds and without other symptoms of overdosage.

Throughout the experimental period the semen quality of the three rams remaining on treatment was maintained at a high level, and the data in table 1 do not indicate any pronounced effect of the treatment, either detrimental or beneficial, on the semen of the rams, Regressions were calculated between the various semen characteristics measured and time. None of the

TABLE 2. EFFECTS OF THYROPROTEIN ON RAM WEIGHTS, SUMMER 1945

Dates	Av. wt. 5 untreated rams	Av. weight 3 treated rams
	lbs.	lbs.
July 17	222.8	205.3
July 27	222.4	192.6
Aug. 3	229.4	190.3
Aug. 12	216.4	186.0
Aug. 20	226.0	197.0
Aug. 27	228.5	202.0

regressions were significant, thus indicating no definite trend during the treatment, in either the control or the treated groups.

From the weight records (table 2) it appears that the treated rams tended to lose weight during the early part of the treatment period even when no other symptoms of hyperthyroidism were present, but that they gained during the latter part of the treatment period and at the end of the trial had almost returned to their starting weights. The control rams gained slightly during the same period.

Second Experiment, Spring 1946

The spring trial period was included in the studies to determine whether the administration of thyroprotein during a period when moderate temperatures prevailed would have the same effects as when administered during the summer months. The treated group received 0.5 gm. daily of a batch of iodinated casein containing 3% thyroxine by chemical analysis, but having four to six times the biological potency of the batch used in the first summer trial.

In this trial a definite detrimental effect of treatment on semen quality was

apparent (table 3). The volume of semen produced was the only semen characteristic which was unaffected by treatment. The initial motility ratings in the treated group dropped suddenly, soon after treatment began, and remained low until treatment ceased, after which a slight improvement became apparent.

TABLE 3. AVERAGES OF CRITERIA USED TO COMPARE SEMEN OF UNTREATED RAMS WITH THAT OF RAMS RECEIVING 0.5 GM. OF THYROPROTEIN DAILY, SPRING, 1946. FOUR RAMS IN EACH GROUP

Date	Volume (cc.)		Init. motility		Motility after 1 hour		Meth. blue reduc. (minutes)		Density (colorimeter readings)	
	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.	Untr.	Tr.
Pre-Treatment Period										
Mar. 23, '46	1.1	1.9	4.2	4.0	3.7	2.5	10.1	18.0	50.0	56.6
Mar. 30, '46	1.2	1.9	3.7	3.7	0.2	0.2	12.5	16.1	46.2	53.5
Apr. 13, '46	1.6	2.7	4.7	3.7	1.0	2.0	27.0	27.8	46.2	57.0
Period of Treatment										
Apr. 19, '46	1.4	1.2	4.7	5.0	1.2	3.0	10.8	18.6	51.0	63.2
Apr. 26, '46	1.3	1.6	4.0	4.7	1.5	1.0	20.1	47.1	51.2	61.0
May 3, '46	1.5	2.3	4.5	2.0	0.5	0.2	19.2	75.8	55.0	68.0
May 10, '46	1.5	1.9	5.0	3.0	2.0	1.0	13.1	71.7	55.0	71.0
May 18, '46	1.2	1.7	4.7	2.7	1.2	0.7	12.6	81.3	52.5	70.0
May 23, '46	1.5	2.0	5.0	2.0	0.5	0.2	10.4	93.6	50.7	62.5
May 30, '46	1.6	1.7	4.2	2.0	1.2	1.2	14.8	94.0	54.5	74.0
Post-Treatment Period										
June 8, '46	1.6	2.0	5.0	1.7	0.5	0.5	6.2	103.7	51.7	79.5
June 14, '46	1.6	2.4	4.7	2.2	0.7	0.7	8.2	76.2	57.7	79.5
June 21, '46	1.8	2.4	4.7	2.6	2.7	2.0	10.5	54.0	57.0	73.6

The motility ratings after one hour at 37° C. tended to be lower for the treated group but there was so much variation in the results that little importance can be attached to the data.

The time required to reduce methylene blue increased sharply early in the treatment period, and after the third week the semen of only one ram of the treated group completed reductions. Improvement became apparent soon after treatment ceased and within three weeks two of the four rams were reducing the methylene blue in a relatively short time. Regressions show the changes in initial motility and methylene blue reduction time in the treated group to be significant or highly significant.

Although regressions were not significant, semen density during the trial period was apparently reduced in the treated group. Densities of treated and untreated groups were fairly comparable until the third week of treatment at which time the densities of the treated group dropped off decidedly. At the end of the trial period, densities were still low in the treated group and remained so during the three post-treatment weeks.

Table 4 gives the weight changes for the spring treatment period. The treated group show a great deal of variation from week to week with the major portion of their 26.7 pounds increase in weight coming in the last week. The control group, on the other hand, gained steadily throughout the experimental period, with an average total gain of 37 pounds per ram being recorded.

TABLE 4. EFFECTS OF THYROPROTEIN ON RAM WEIGHTS, SPRING 1946

Dates	Av. weight 4 untreated rams	Av. weight 4 treated rams
	lbs.	lbs.
April 16	187.5	162.5
April 23	191.1	171.7
April 26	199.0	164.7
April 30	198.7	171.7
May 14	212.0	174.0
May 28	224.5	189.2

Third Experiment, Summer 1946

The third trial period during the summer of 1946 was planned to include two treated groups of four rams each, and one control group of four rams. The first treated group received 0.5 gm. of iodinated casein daily and the second group 1.5 gm. daily. The material used was from the same batch as that used in the spring trial. The period of treatment began July 12, 1946 and extended for six weeks.

During the treatment period, one ram from each treated group died. Ram No. 181 (on a dose of 0.5 gm. daily) died two weeks after treatment began due to the effects of urinary stoppage, caused by the presence of several urinary calculi. Ram No. 70 (on a dose of 1.5 gm. daily) died during the 4th week of treatment, of catarrhal bronchopneumonia and catarrhal rhinitis and tracheitis.[3] He had shown a slight nasal discharge for some time prior to treatment, and it is possible that the treatment aggravated a pre-existing condition. At the time of his death his semen had dropped in quality. Data

[3] Post mortem examinations were made by Dr. D. R. Cordy, College of Veterinary Medicine, Pullman, Washington.

TABLE 5. AVERAGES OF CRITERIA USED TO COMPARE SEMEN OF UNTREATED RAMS WITH THAT OF RAMS RECEIVING 0.5 GM. OR 1.5 GM. OF THYROPROTEIN DAILY, SUMMER 1946

Date	Volume (cc.)			Initial Motility			Motility after 1 hour			Methylene blue reduc. (minutes)			Density (colorimeter readings)		
	Untr.*	0.5 gm.**	1.5 gm.**	Untr.	0.5 gm.	1.5 gm.	Untr.	0.5 gm.	1.5 gm.	Untr.	0.5 gm.	1.5 gm.	Untr.	0.5 gm.	1.5 gm.
Pre-Treatment Period															
June 21, '46	1.8	1.5	1.2	3.5	4.0	5.0	2.0	0.5	4.0	32.7	20.6	12.6	57.5	60.0	57.6
June 28, '46	2.0	1.6	2.0	4.5	4.3	4.6	3.5	2.6	3.0	37.5	21.6	24.1	60.0	65.6	61.6
July 5, '46	1.8	1.6	1.8	4.7	5.0	4.6	3.5	3.0	4.3	15.2	9.8	9.3	60.0	64.6	64.0
Period of Treatment															
July 12, '46	1.7	1.5	1.9	5.0	4.3	5.0	3.2	4.0	3.6	11.2	7.3	10.3	59.7	63.3	63.6
July 20, '46	1.9	1.3	2.1	3.7	5.0	5.0	2.7	4.0	3.3	47.2	15.6	15.8	64.2	66.0	66.3
July 27, '46	1.8	1.3	2.4	4.2	5.0	5.0	2.0	4.6	3.3	35.7	13.5	10.6	—	—	—
Aug. 3, '46	1.7	1.7	1.8	4.0	5.0	3.6	3.0	4.0	3.3	36.3	11.3	45.3	59.7	65.5	62.6
Aug. 10, '46	1.8	1.3	1.2	4.5	5.0	4.0	3.0	2.6	3.0	14.2	10.0	30.0	60.0	60.3	61.0
Aug. 17, '46	1.6	1.8	1.9	4.2	5.0	4.0	2.2	3.6	4.0	49.0	9.0	19.6	68.7	61.0	66.6
Post-Treatment Period															
Aug. 24, '46	2.1	1.5	2.1	4.5	4.0	3.3	4.2	3.3	3.3	37.7	13.0	14.0	64.7	61.3	59.0
Aug. 31, '46	1.9	1.6	1.5	4.2	4.6	4.0	2.0	3.0	3.6	38.8	10.6	12.0	65.0	59.0	64.3

* Av. for four rams.
** Av. for three rams.

on the semen of neither ram have been included in the averages. From the information available, it is impossible to determine whether the deaths of these rams can be attributed to the effects of treatment.

The average semen quality as indicated by the various evaluations made (table 5) does not appear to have been greatly affected by treatment in this experiment. The rams receiving 0.5 gm. of iodinated casein daily had semen of high average initial motility which reduced methylene blue on the average faster than the semen of the rams in either the control group or the group receiving 1.5 gms. This is in contrast to the marked deleterious effect of the same dosage during April and May.

The motility ratings after one hour are higher in both treated groups than in the controls. Again this is in contrast to the results obtained in the spring months.

There was no apparent difference in densities in the treated and untreated groups.

The weights of all rams in all groups tended to be lowered during the third and fourth weeks of treatment and to increase somewhat in the last two weeks. The control group and the group receiving 0.5 gm. returned to approximately the starting weight at the end of the trial and the group receiving 1.5 gms. lost an average of 12 pounds. (table 6).

TABLE 6. EFFECTS OF THYROPROTEIN ON RAM WEIGHTS, SUMMER, 1946

Dates	Av. weight 4 untreated rams	Av. weight 3 rams treated 0.5 gm.	Av. weight 3 rams treated 1.5 gm.
	lbs.	lbs.	lbs.
July 16	235.5	195.0	203.6
July 23	235.5	195.0	197.3
July 30	228.5	189.0	191.3
Aug. 6	223.7	182.6	186.3
Aug. 13	227.5	192.0	186.3
Aug. 20	234.7	196.6	191.6

Discussion

In each of the three experiments reported in this paper, thyroprotein was administered to rams in dosages sufficient to cause weight losses during the early parts of the experimental periods. In each of the three experiments the rams on treatment apparently developed a tolerance for the material and during the last two or three weeks of treatment tended to gain weight and, in some cases, made a total gain for the experimental period approaching that made by the control rams. On the basis of these weight records, together with observations upon the health of the rams, it appears that with the ex-

ception of two rams in experiment 1 the dosages given were somewhat above the normal physiological requirements of the rams but that the dosages were small enough that no harmful effects upon the general health of the rams were produced.

When thyroprotein was administered to rams during the months of April and May, adverse effects upon the semen production were clearly apparent within three weeks after treatment started. The motility, liveability, and density of the semen were affected greatly and the metabolic potential of the semen was apparently also greatly reduced since the time required for the reduction of methylene blue increased approximately five times.

The results of experimental work conducted during the months of July and August during the years of 1945 and 1946 indicate that at this season of the year, under conditions prevailing in Pullman, Washington, there were no harmful effects of treatment with thyroprotein so long as the dosages did not go too high, and that, in some cases there were suggestions that treatment may have resulted in slightly improved semen quality. The first year's work (1945) was carried on with a group of rams in which the control rams had semen of excellent quality during the entire experimental period, apparently not having been affected by any seasonal deterioration in semen quality. The treated rams, likewise, produced semen of excellent quality throughout the treatment period with no evidence of any differences between these groups being apparent.

In the second experiment (1946) the semen produced by the control rams was not of as high average quality as that produced by the rams used during the 1945 experiment, being somewhat lower in initial motility on the average, requiring somewhat longer to reduce methylene blue, and having a somewhat lower density. Although the differences were small, the rams in the treated group receiving 0.5 gm. of iodinated casein daily produced semen which was somewhat higher in average motility, reduced methylene blue somewhat more rapidly on the average, and did not differ appreciably from the semen produced by the control rams in density. The data thus suggest that there may be seasonal differences in the tolerance of rams for thyroprotein, and, although there is little foundation for such a hypothesis, it might be possible that the endogenous production of thyroxin was greater in rams during the spring months than during the summer, and that additional amounts of active material administered at this time resulted in an over-supply and thus adversely affected semen production. The same line of reasoning leads to the hypothesis that thyroxin production is lowered during the summer months and that the administration of thyroid active materials did not bring the total amount available above the physiological tolerance of the experimental animals. Determinations of the basal metabo-

lism of large numbers of rams during these two seasons would be interesting in pointing out the possible truth in the above hypotheses.

The experience with two rams during the summer of 1945 indicates quite definitely that over-dosages of thyroid active material result quite promptly in deterioration of the semen. Furthermore, the tolerance for the thyroid-active material used in this experiment was apparently not correlated with weight since the two rams adversely affected were either average or above the average in weight among the animals treated. The other animals in the group tolerated the same dosage quite well. Thus, the indiscriminate dosing of rams even of the same weight with a given amount of this material is likely to lead to disastrous results, at least in certain cases.

Summary

Groups of from three to five rams were treated with thyroprotein during both spring and summer months at dosages sufficient to cause pronounced weight losses during the first weeks of the treatment. The semen of the various treated groups was compared with that produced by control rams.

Treatment during the months of April and May had an apparent deleterious effect on semen quality as measured by initial motility, liveability, density, and ability to reduce a solution of methylene blue. During the summer months rams which tolerated the dosage given produced semen which was either equal to or slightly above the semen produced by the control rams in quality.

The ability to tolerate thyroprotein was apparently not related to body weight and in some rams in which excessive weight losses occurred following the administration of the experimental materials, deterioration in semen quality was immediate and drastic.

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ABSORPTION AND ELIMINATION OF THIOURACIL IN RUMINANTS[1]

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THE recent discovery that the formation of hormone by the thyroid gland can be suppressed by the administration of thiouracil and related compounds provides a useful approach for investigations on the role of the thyroid in the productive processes of domestic animals. In nonruminant animals, including swine, chickens and turkeys, the administration of thiouracil for a limited time during the fattening period has resulted in either an increase in economy of gains, an improvement in market grade, or in some cases an improvement in both of these measures.

The extension of this type of investigation to ruminant animals has been limited by the paucity of information on what actually constitutes a physiologically effective dosage of thiouracil in such animals and also the difficulty of administering the compound under normal feeding conditions.

Turner, Reineke and Schultze (1944) presented a preliminary report on the dosages of thiourea required to produce thyroid hypertrophy in lambs and young goats.

These observations were borne out later by Pipes and Turner (1946) who indicated that relatively high levels of goitrogens were required to maintain effective blood levels in ruminant animals. These workers showed that over a period of 22 hours thiouracil levels could be maintained in the blood of 125 pound calves by oral administration of 2 gms. of the drug at 12 hour intervals. Limited studies of absorption and elimination of some goitrogens were reported by the same authors. They found that thiouracil was rapidly eliminated from the blood following single doses, but information concerning extensive continuous intake was limited.

Andrews *et al.* (1947) reported that the thyroids of lambs receiving from 0.175 to 0.544 gm. of thiouracil daily were significantly enlarged, indicating inhibition of thyroid function. The largest numbers of top grade carcasses occurred in the lots receiving 0.175 and 0.333 gm. of thiouracil per lamb daily. The administration of thiouracil to steers at the levels of 2.0, 4.0 and 6.0 gm. per steer per day did not significantly affect the dressing percentage and degree of finish although there was a tendency toward improvement of both of these characteristics (Beeson, Andrews and Brown, 1947).

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Material and Methods

The experimental animals used in this study were dairy bull calves four to eight weeks old and yearling female goats. All animals were maintained under normal feeding and management conditions, without iodine supplementation. The trials were conducted between November 1 and April 1.

In order to study the possible effects that the rumen might have on the dosage level required and the relative rate of absorption of the drug into the blood stream, groups of animals of each species were administered both oral and subcutaneous doses for comparison.

A 5 percent solution of thiouracil adjusted to pH 9.0 and kept at body temperature was used as a stock solution for subcutaneous injections. Oral administrations were given in capsules with a capsule gun.

Plasma thiouracil levels were determined by a method previously reported (Olson, Ely and Reineke 1947).

Results and Discussion

Oral and Subcutaneous Single Doses to Goats

For the initial study of oral administration to ruminant animals four levels of thiouracil were given to four goats. On the basis of gms. per kg. of body weight the four levels were: 0.015, 0.030, 0.060, and 0.120 gms. Blood samples were taken from the jugular vein at 2, 4, 6, 8, 11 and 24 hours following the oral dose. The plasma thiouracil concentration (figure 1*A*) reached a peak in the plasma between 4 and 8 hours with a somewhat constant level over this period. It is of interest that the plasma values were roughly proportional to the dosage levels, e.g. the dosages increase in geometrical progression and the plasma levels at any given time approximate the same relationship.

In order to compare the relative subcutaneous results, two goats were injected at the two higher levels studied for oral administration (0.06 and 0.12 gm. per kg. of body weight). Blood samples were taken at the same time intervals as for oral study.

In contrast to oral administration the peak concentration was reached at 4 hours or before and drops very rapidly (figure 1*B*). On levels of both 0.06 and 0.12 gms. per kg. of body weight the high plasma concentrations reached in the injection study were approximately twice those for the oral route. The high injection values were 8.2 and 5.0 mg. percent while the corresponding oral values were 4.2 and 2.2 mg. percent.

Oral and Subcutaneous Single Dosage to Calves

The calf study was conducted precisely the same as that for goats except that the dosage levels were 0.10 and 0.20 gms. per kg. of body weight by

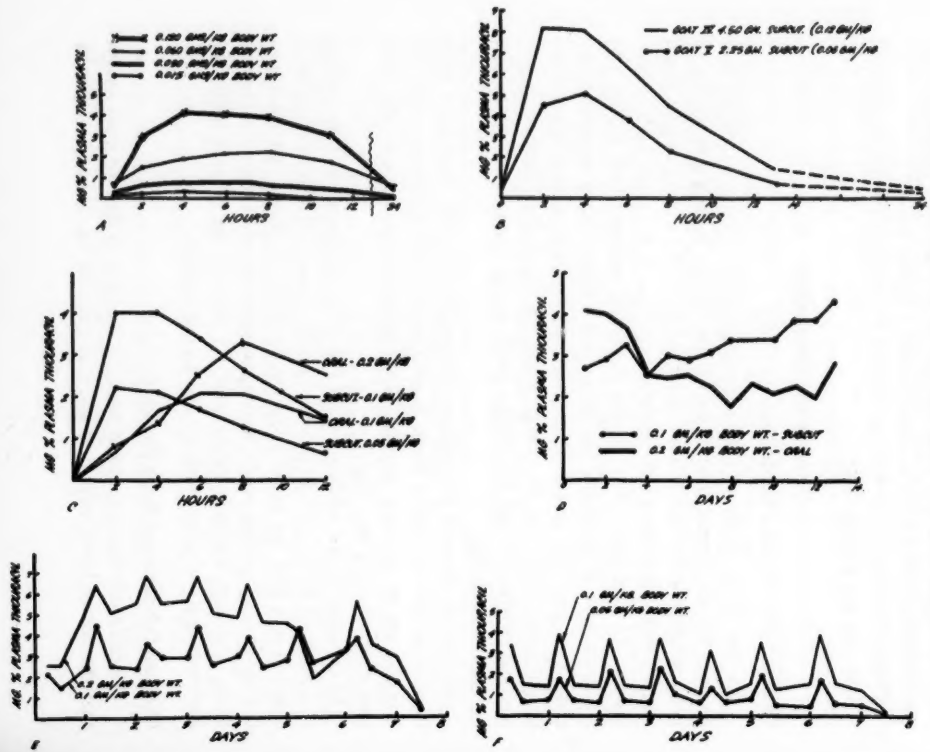

Figure 1. Thiouracil in the blood plasma of calves and goats after oral and subcutaneous administration. The dosage figures given on the charts represent the total amount given daily. A. A single dose of thiouracil given orally to goats at four different levels; B. A single dose given to goats by subcutaneous injection at two different levels; C. A single dose of thiouracil given to calves by oral or subcutaneous administration; D. Daily maximum levels of thiouracil in blood plasma of goats on repeated oral administration at twelve hour intervals; E. Daily minimum and maximum levels of thiouracil in the blood plasma of calves during repeated oral administration at twelve hour intervals; F. Daily minimum and maximum levels of thiouracil in the blood plasma of calves during repeated subcutaneous administration at twelve hour intervals.

the oral route and 0.05 and 0.10 gms. per. kg. of body weight when given subcutaneously. Blood samples were taken from the jugular vein 2, 4, 6, 8 and 12 hours after administration. Figure 1*C* shows that the plasma thiouracil concentrations following oral administration reached the maximum value around 6 to 8 hours whereas the levels obtained by subcutaneous administration were highest at 4 hours. This is similar to the results obtained with goats. Maximum blood plasma thiouracil levels were reached more rapidly and also declined more rapidly with subcutaneous than with oral administration.

Oral and Subcutaneous Continued Dosage in Goats

To study the blood plasma levels of thiouracil during continued oral administration to goats, two animals received 0.2 gm. of thiouracil daily per kg. of body weight, divided into equal doses, at 8:00 A.M. and 8:00 P.M. Daily blood samples were taken for 13 days at 1:00 P.M. for thiouracil determinations. Blood plasma thiouracil values decreased during the first four days of administration and then maintained a nearly uniform concentration for the remainder of the period (figure 1*D*). This oral dosage level at 12 hour intervals was sufficient to maintain effective blood plasma thiouracil concentrations.

Thiouracil was administered to two goats subcutaneously at the level of 0.1 gm. per kg. of body weight. Injections were given and blood samples were taken at the same time intervals as for the oral administration described above. The average blood plasma thiouracil values for these two animals are shown in figure 1*D*. These animals had a reasonably constant range of plasma thiouracil concentrations during the first ten days and then a slight increase. It is apparent that 0.1 gm. of thiouracil daily per kg. of body weight injected subcutaneously twice daily will maintain uniform blood plasma thiouracil levels.

Oral and Subcutaneous Continued Dosage to Calves

A study of blood plasma thiouracil concentrations was made with two calves receiving oral administration of 0.1 and 0.2 gm. of thiouracil daily per kg. of body weight, divided into equal doses administered at 8:00 A.M. and 8:00 P.M. Blood samples were obtained at 8:00 A.M., 1:00 P.M., and 8:00 P.M. over a period of 8 days. The blood plasma thiouracil levels of these two calves are shown in figure 1*E*.

Administration of 0.1 gm. of thiouracil daily per kg. of body weight was sufficient to maintain blood plasma thiouracil levels in the vicinity of 3.0 mg. percent when given at 12 hour intervals which is comparable to normal feeding practices. In most cases there was greater than one mg. percent dif-

ference between the lower values taken 12 hours after administration and the higher values taken 5 hours after administration. It is apparent that the animal receiving the higher dosage did not receive the complete dose on the fifth day as the blood value dropped markedly but returned to the normal pattern on the sixth day.

Two calves were given subcutaneous injections of 0.05 and 0.1 gm. of thiouracil daily per kg. of body weight for a period of 8 days (figure 1*F*). Injections were given and blood samples obtained at the same times as previously described for the oral administration to calves (figure 1*E*). Subcutaneous injection of 0.1 gm. of thiouracil daily per kg. of body weight was sufficient to give blood plasma concentrations of 3.0 mg. percent although the low plasma values 12 hours after dosage fell to lower levels than with the same oral dosage level. This is in agreement with the more rapid elimination rate with subcutaneous administration (figure 1*C*).

Discussion

The effective physiological level of thiouracil administration has not been established for most species. In some experiments designed to study the effect on market quality of meat animals where apparently effective thiouracil dosage levels have been given, corresponding blood levels have not been determined. Our results relate the respective plasma thiouracil concentrations with various dosage levels administered orally and subcutaneously. However, the minimal level of thiouracil in the blood plasma that will effectively inhibit thyroid secretion in ruminants has not been established. Other experimental approaches will be required to establish this endpoint.

Williams (1944) has reported rapid absorption of thiouracil from the gastrointestinal tract of man, the maximum levels in the blood being reached in 30 minutes in certain cases. Paschkis *et al.* (1945) has also reported rapid absorption of orally administered thiouracil in humans and rapid excretion in the urine. Pipes and Turner (1946, 1946*a*) reported high concentrations of thiouracil in the blood of chickens soon after feeding.

In comparison with non-ruminants our results with calves and goats show a slower rate of absorption from the digestive tract, the maximum blood plasma concentrations being reached in 4 to 8 hours following a single oral dose. Similar results for the goat have been reported by Pipes and Turner (1946). In the study of single dosages of thiouracil in ruminants we have shown that subcutaneously administered thiouracil is absorbed and eliminated more rapidly than with oral dosage. Plasma thiouracil concentrations following subcutaneous administration were approximately twice those following comparable oral dosage. Progressive increases in blood plasma

thiouracil concentrations were secured with increases in oral dosage levels studied.

It is of practical importance that blood thiouracil levels may be maintained by administration at 12 hour intervals. Our results show that thiouracil is practically eliminated from the blood stream of ruminants 24 hours after discontinuing administration. This is true following continued administration as well as with a single dosage, supporting the evidence that there is very little storage or accumulation of thiouracil in the body tissues.

Summary

The absorption and elimination of thiouracil was studied in calves and goats following oral and subcutaneous administrations.

Maximum blood plasma thiouracil concentrations were reached in 4 to 8 hours following oral administration and in 2 to 4 hours following subcutaneous administration. Over the range studied, blood plasma thiouracil concentrations were approximately proportional to dosage levels.

Single doses administered subcutaneously gave approximately twice the blood plasma thiouracil concentration as the same dosage level administered orally.

Essentially uniform blood plasma thiouracil concentrations were maintained in ruminants with oral and subcutaneous administration at 12 hour intervals.

Thiouracil was practically eliminated from the blood stream within 24 hours after cessation of administration.

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EFFECT OF FEEDING THIOURACIL TO SWINE ON THE RATE OF GAIN AND WEIGHT OF THE THYROID GLAND[1]

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CONSIDERABLE interest has developed in the effects of feeding thiouracil and related compounds to various species as chemical agents which depress the activity of the thyroid gland. The possibility, therefore, that the ingestion of thiouracil would result in a more rapid rate of fattening and less feed required to produce a unit of gain has been investigated by several workers. Muhrer and Hogan (1945) observed that Chester White and Poland China Crossbred pigs gained more rapidly and more economically when 0.2 percent thiouracil was added to the ration in paired feeding experiments. Van Der Noot *et al.* (1947) have reported in a recent paper that 0.25 percent of thiouracil was more effective than 0.15 or 0.20 percent for increasing the rate of gain and the economy of feed utilization. Berkshire hogs were used with an initial weight of 200 pounds. These results are in contrast to those reported by Willman *et al.* (1946). The latter workers found that when either 0.1 and 0.2 percent thiouracil was added to the ration, a slower rate of gain and a decreased economy of feed utilization occurred.

In the present study the effect of feeding 0.25 percent of thiouracil in the ration for 51 days to both barrows and gilts of two different breeds was carried out to obtain additional information on the deleterious or beneficial effect of feeding the drug as well as on any differences attributable to the breed used. Data were also obtained on the effect of feeding thiouracil on the weight of the thyroid gland of the animal.

Experimental

Thirty-two fall pigs were divided into 8 lots of four pigs each. They were being fed only on garbage when chosen for this work. Two breeds, Duroc Jersey and Hampshire, were used, each being represented by 16 animals, 8 barrows and 8 gilts. Each lot consisted of 2 barrows and 2 gilts of the same breed, and the animals were grouped on the basis of body weight and general similarity of type. Since the initial weight of the animals ranged from 114 to 187 pounds, care was taken to make the average initial weights of all lots as equal as possible. The lots were numbered from 2 to 8, with num-

[1] Some of the data were taken from a thesis submitted by Ramon Acevedo in partial fulfillment of the requirements for a Master of Science degree. The assistance of Prof. C. B. Godbey with the statistical analyses is greatly appreciated.

bers 1, 2, 5, and 6 composed of Hampshire hogs, and 3, 4, 7, and 8 of Duroc Jerseys. Lots 1 to 4 were placed on the control ration and lots 5 to 8 on the experimental ration which contained 0.25 percent thiouracil.[2] With this distribution 2 replications per breed were obtained in each treatment.

The basal ration used consisted of 82.5 pounds of milo grain, 10 pounds alfalfa leaf meal, 6.5 pounds meat scraps and 1 pound salt. The experimental ration contained 0.25 percent thiouracil which replaced an equivalent amount of the above mixture. The feeding trial extended over a 51 day period, from April 17, 1947 to June 6, 1947, and the animals were fed *ad libitum*. Records were kept by lot of all the feed consumed during each weighing period. The data on weight gains were treated statistically by an analysis of variance (Snedecor, 1946).

At the close of the experiment 8 animals (four from each treatment) were selected for carcass studies. The remaining animals which received the thiouracil were fed the control ration. After periods of 10 and 17 days, 16 and 8 animals, respectively, were slaughtered and the weight of the thyroid glands measured. Some of the glands were prepared for histological study.[3]

Results and Discussion

The growth rates for each weighing period of both the control animals and those fed thiouracil are shown in figure 1. The addition of 0.25 percent thiouracil to the ration reduced the growth rate of the treated hogs as measured by their gain in weight. That the rate of gain was markedly retarded by the ingestion of thiouracil is indicated by the average total gain per pig; 74 pounds for the control animals, and 38 pounds for the animals fed thiouracil.

As seen in figure 1, the average rate of gain for the treated animals was the same as that for the controls in the first 9 day period. The animals fed thiouracil made higher rates of gains in the second period, when the control groups made their lowest gains. This may be accounted for by the subnormal gains of the control animals in lots 1, 2, and 3 in this period, although the reason for this slow rate of gain is not known. In the 3rd weighing period all the Hampshire gilts and one barrow fed thiouracil lost weight, and in subsequent periods some animals continued to lose weight. Since the experimental group performed normally during the first two periods of the feeding trial, it seems that thiouracil fed at the 0.25 percent level did not influence the rate of growth during this period of its administration. The fact that the average daily gains of the treated animals were reduced as the

[2] We are indebted to Lederle Laboratories Division, American Cyanamid Co., Pearl River, New York, for supplying the thiouracil used in this work.

[3] We are indebted to Dr. C. N. Barron of the Department of Veterinary Medicine for the histological examinations.

feeding trial progressed up to its termination and that some of the experimental animals lost weight after 18 days indicates that a more pronounced depression occurs with prolonged feeding of the drug.

The pigs fed the basal ration gained at the rate of 1.46 pounds daily, 1.43 by the Hampshires and 1.49 pounds by the Duroc Jerseys. Those fed the thiouracil ration gained at the rate of 0.75 pound daily, 0.53 by the Hamp-

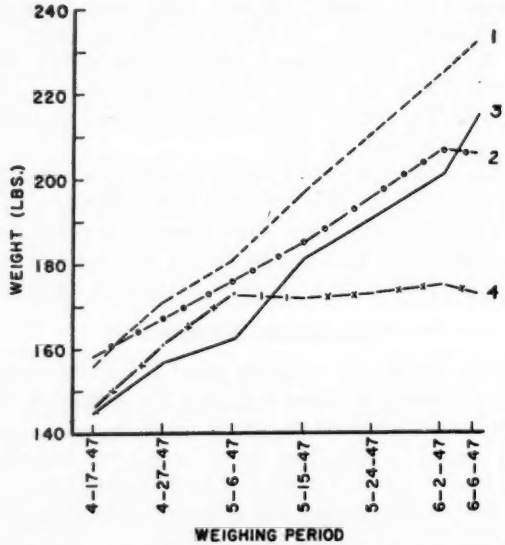

Figure 1. A comparison of rates of gain of Hampshire and Duroc Jersey swine fed the basal ration or the basal ration plus 0.25 percent thiouracil. Group 1—Basal ration (Duroc Jersey). Group 2—Basal ration + thiouracil (Duroc Jersey). Group 3—Basal ration (Hampshire). Group 4—Basal ration + thiouracil (Hampshire).

shires and 0.97 by the Duroc Jerseys. A similar average daily gain was reported by Willman *et al.* (1946) for animals fed thiouracil at the 0.1 percent level. The data on the weights, gains and feed consumption are shown in table 1.

During the first period of the feeding trial both groups consumed similar amounts of feed, but thereafter the feed intake of the treated animals was consistently reduced. This was noted especially in the case of the Hampshires which consumed an average of 4.57 pounds of feed per day as compared to 5.25 pounds by the Duroc Jerseys. The control groups consumed an average of 8.06 and 8.76 pounds per day respectively, for the two breeds. The value

of these last figures is limited by the fact that lots 1 and 2 spilled more feed than lots 3 and 4, and it was more difficult to keep an accurate record of their feed consumption.

The control groups also utilized feed more efficiently than those fed thiouracil. Feed required to produce a pound of gain on the basal ration was 5.63 for the Hampshires and 5.19 pounds for the Duroc Jerseys as compared with 8.72 and 5.41 pounds for the respective breeds fed thiouracil. In the treated groups the difference in feed utilization between breeds was quite marked. The figures for feed utilization are regarded as approximate in that rigid control of feed spillage was not achieved. To obtain further information on the effect of thiouracil on feed utilization it would be desirable to obtain data on the food consumption of individual animals.

A statistical analysis made by breeds showed that the mean square for treatment was highly significant for the Hampshires and also for the Durocs. The mean square for the groups was found to be nonsignificant, indicating that the pigs in the pens treated alike were quite consistent in mean gains.

TABLE 1. INFLUENCE OF FEEDING 0.25 PERCENT THIOURACIL ON FEED CONSUMPTION AND GAINS

Items compared	Hampshire		Duroc Jersey	
	Basal	Basal plus thiouracil	Basal	Basal plus thiouracil
No. of pigs	8	8	8	8
Av. initial wt. lb.	144.5	146.2	155.9	154.1
Av. final wt. lb.	217.4	173.2	232.1	203.6
Av. daily gain, lb.	1.43	0.53	1.49	0.97
Av. daily feed, lb.	8.06	4.57	7.76	5.25
Feed per lb. gain, lb.	5.63	8.72	5.19	5.41

The difference in mean gain between breeds fed the control ration is not significant, but there is a highly significant mean difference in gains between the breeds fed the thiouracil ration. These data show that, since the response to feeding thiouracil appears to be dependent on the breed used, conclusions on the effect of feeding this compound should be based only on the breeds studied, and further work will be needed to evaluate the response in other breeds.[4] An explanation for the difference in response attributable to the breed used is not readily apparent. The data suggest that the breed of animals used should be considered in interpreting the results obtained by various workers.

[4] Since this manuscript was prepared a paper has been published on the effect of feeding 0.1 percent thiouracil to different breeds of swine (McMillen, W. N., Reinecke, E. P., Bratzler, L. J., and Francis, M. J. JOURNAL OF ANIMAL SCIENCE. 6: 305–309). These workers also observed a breed difference and a slower rate of gain when thiouracil was fed.

Thiouracil at lower levels has been shown to inhibit growth. Willman *et al.* (1946) found that thiouracil added to the ration of growing swine, at the 0.2 percent level, markedly depressed the rate of growth and the appetite of pigs. Beeson (1947—Personal communication) found similar results when feeding thiouracil at the 0.1 percent level. The higher rates of gain of the animals fed the 0.2 percent thiouracil ration as compared to that observed for control animals in the experiments of Muhrer and Hogan (1945) may be attributed largely to limiting the feed intake of the control groups to that of the groups fed thiouracil. As pointed out by them, the group fed the control ration would have gained more if they had been fed *ad libitum*. These workers used a 28 day feeding period and from the present work, some beneficial effect due to thiouracil ingestion was noted in the first 18 days. Therefore the length of the feeding period appears to be very important in interpreting the effects of thiouracil.

Van Der Noot *et al.* (1947) added the same level of thiouracil as used in this study and found that the treated animals made faster gains. The difference between their results and those reported in this study may be attributed to the higher initial weight of the animals used by them, as well as the difference in breed of animals or in environmental conditions, especially temperature, under which these experiments were carried out.

Carcass studies failed to reveal any detectable difference that could be attributed to the thiouracil treatment, and a comparison of the proportion of commercial cuts showed both groups to be similar in this respect.

Although the weight of the thyroid gland was measured 10 or 17 days after the thiouracil treatment had been discontinued, a significant difference between the thyroid weights of the control and the treated animals was obtained. The average weight in milligrams of thyroid gland per pound of carcass weight was found to be 44 for the control animals and 128 for the animals fed thiouracil (table 2). These results were obtained for animals that were killed 10 days after discontinuing the ration containing thiouracil. Seventeen days after cessation of thiouracil the weight of the thyroid glands was still significantly heavier than for the pigs on the basal ration. Expressed in milligrams of thyroid per pound of carcass the figure for 4 pigs fed thiouracil was 122 as compared with 52 mg. for pigs on the basal ration. An increase in weight of the thyroid gland when the animals were fed thiouracil has been reported by Beeson *et al.* (1947) for steers, by Andrews *et al.* (1947) for lambs, Schultze and Turner (1945) for goats and chickens and Mixner and Upp (1947) for chickens.

Histological examination of the thyroid glands of the treated animals showed a marked hyperplasia of the follicular epithelium with some increase in the size of the cells, greatly reduced colloid content, and an increase in

size of the follicles. The glands of the animals that had been fed the basal ration for 17 days after discontinuance of treatment were apparently returning to normal, as the hyperplasia was less marked, more colloid was found in the follicles, and the epithelial cells were decreasing in size.

TABLE 2. EFFECT OF THIOURACIL ON WEIGHT OF THYROID GLAND. ANIMALS WERE KILLED 10 DAYS AFTER FEEDING OF THIOURACIL WAS DISCONTINUED

Breed*	Sex**	Carcass weight, lb.	Thyroid weight, gm.	Thyroid weight; mg. per lb. of carcass weight
		Basal Ration		
H	M	187	5.62	030
H	M	164	5.58	034
H	F	126	4.78	037
H	F	171	6.42	038
D	M	154	11.22	073
D	M	205	8.06	039
D	F	140	7.99	057
D	F	185	8.52	046
Average		165	7.26	044
		Basal Ration+0.25 percent Thiouracil		
H	M	116	18.32	158
H	M	125	17.86	143
H	F	108	18.87	175
H	F	138	17.55	127
D	M	174	24.61	141
D	M	154	16.49	107
D	F	154	14.93	097
D	F	134	9.89	074
Average		128	17.32	128

* H—Hampshire, D—Duroc Jersey.
** M—Males, F—Females.

It is well known that changes in thyroid activity are related to season and that probably seasonal variations are in a large measure due to differences in temperature. It has also been shown that the iodine content of the thyroid gland of mammals is lower in midsummer than during the winter months. This suggests that animals in sub-tropical and tropical climates secrete less thyroxine than those in the temperate climate. Therefore, 0.25

percent thiouracil may be an excessive amount to be used to demonstrate beneficial effects on the rate of fattening and food utilization when conducted under the environmental conditions present during the course of this study.

More work is needed on the effects of feeding different levels of the drug to several breeds and the influence of initial weight before the possible beneficial effects of thiouracil can be determined. Furthermore, studies conducted during different seasons of the year and for different feeding periods should be made. Further work on the physiological action of thiouracil and similar drugs is also needed. Studies on white blood cell counts would be valuable as the feeding of thiouracil has been found to cause agranulocytosis in several species of animals, including humans. A reduction in the number of leucocytes in the blood may increase the incidence of disease, a factor that is of importance in animal production, especially in dry-lot feeding. No data are available on the influence of these compounds on the nutritive value of meat or the effects on the metabolism and utilization of various nutrients by the animal.

Summary and Conclusions

The addition of 0.25 percent thiouracil to the ration of growing Hampshire and Duroc Jersey swine was found to depress the growth rate. The weight gains of animals were so reduced that the control animals nearly doubled the gains made by the group fed thiouracil. The controls made a total gain per pig of 74 pounds as compared to 38 pounds by the animals fed thiouracil in a 51 day period. Thiouracil did not appear to reduce the rate of gain during the first 9 to 18 days of the feeding trial, but a progressive reduction in the rate of gain was observed thereafter. The feed intake and feed efficiency was also lower for those animals fed thiouracil.

A difference in response to treatment was observed between the two breeds used in this work. The Duroc Jersey hogs consumed a larger amount of feed than the Hampshires and attained higher gains as well as a higher efficiency of feed utilization.

Carcass studies failed to reveal any gross differences in the commercial cuts, between the control animals and those fed thiouracil.

The ingestion of 0.25 percent thiouracil in the ration significantly increased the weight of the thyroid gland. Seventeen days after cessation of treatment the increased weight of the thyroid still persisted, but the weight of the gland of the groups fed thiouracil was lower than observed for animals killed 10 days after the feeding of the drug was discontinued.

Histological examination of the thyroid glands of the animals that had been fed thiouracil showed an increase in height of the epithelium, greatly reduced colloid content, and an increase in size of the follicles.

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VITAMIN A, VITAMIN C AND NIACIN LEVELS IN THE BLOOD OF SWINE[1]

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THE significance of blood composition in studying livestock nutrition has been shown by results from a number of experiments. One of the most classic examples was the work of Hart and coworkers (1929) with anemia in suckling pigs.

The blood studies reported in this paper were prompted because of an epidemic of scours in suckling pigs in Wisconsin swine herds. There was evidence that the digestive disturbance might be of nutritional origin because the symptoms of the disorder were similar to those found in certain vitamin deficiencies.

Experimental

Pigs of the Poland China, Chester White, and Yorkshire breeds from the Station swine herd were used as experimental animals. They ranged in age from newborn to approximately 5 months of age and were selected from 4 crops of pigs including spring and fall farrowings. The pigs were selected at random so as to include animals of varying ages. No effort was made to follow the same pigs through the 5-month period because of the relatively high rate of mortality during the nursing period. However, many of the same pigs were used intermittently during the entire period.

The dams of the pigs were fed a well-balanced ration containing animal and plant sources of protein, common farm grains, and essential minerals. They had access to pasture in season, and received good quality ground legume hay when not on pasture. The pigs received a similar ration, and creep feeding began when the pigs were about 4 weeks of age.

Blood samples were secured according to the method described by Carle and Dewhirst (1942). A 15 cc. centrifuge tube was used to collect the samples of blood which were placed into an iced thermos bottle immediately after collection. The number of pigs bled at one time was limited so that the analysis could be started within 2 hours after the first pig was bled.

Only 5 cc. of blood were taken from pigs less than 1 day of age to minimize any possible physiological reaction. Fifteen cc. of blood were taken from older animals which provided enough material for vitamins A, C, and niacin

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determinations. Newborn pigs were bled immediately after they were farrowed and then were returned promptly to their mothers.

Vitamin A determinations were made according to the method described by Kimble (1939), vitamin C according to the method described by Mindlin and Butler (1938), and niacin according to the method described by Strong (1946).

Results and Discussion

Figure 1 shows the vitamin C curve for pigs from the period before nursing until they became 10 weeks of age. This curve is based on the determinations of 132 blood samples. Each point on the curve represents an average value taken from approximately 10 samples.

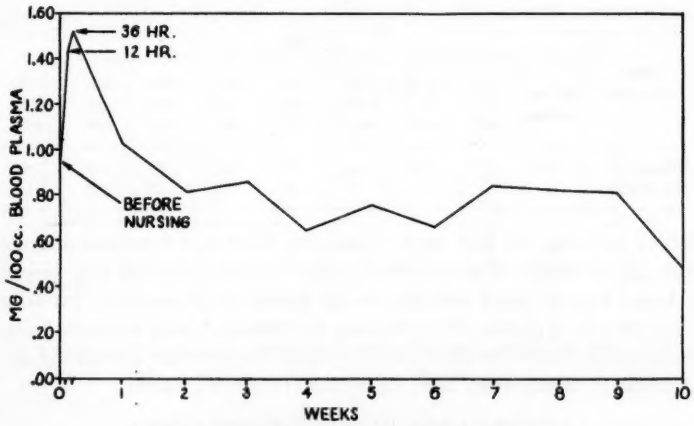

Figure 1. Blood plasma vitamin C of pigs weaned at 8 to 9 weeks of age.

The average vitamin C level of newborn pigs was .96 mg. per 100 cc. of plasma, a value that was higher than the average for any time after the second week. It is interesting to note that this level is considerably above that found for pregnant sows (table 3).

Immediately after birth the vitamin C rose sharply and reached a maximum when the pigs were about 36 hours of age. Two of the 8 pigs used at this age had a vitamin C concentration higher than 2 mg. per 100 cc. plasma. There was relatively little variation between the vitamin C levels of individual pigs at birth. However, a wide variation in concentration was found after ingesting colostrum. The high average of 1.52 mg. at 36 hours declined gradually and became constant at approximately .8 mg. by the second week.

The vitamin C values fluctuated during the middle of the suckling period, but regained the level of approximately .8 mg. during the last 3 weeks of the suckling period. After the ninth week the values were reduced to almost half, which coincides with the weaning date. The average plasma concentration of vitamin C remained between .4 and .5 mg. until the pigs were 5 months of age. Vitamin C values ranged from .19 to 2.54 mg./100 cc. blood plasma.

As shown in table 1, the behavior of vitamin A is somewhat different from that of vitamin C. The vitamin A in the 2 pigs bled before nursing was relatively low, having only .1 γ vitamin A per 1 cc. of blood plasma. The ingestion of colostrum induced a gradual increase and reached a maximum

TABLE 1. PLASMA VITAMIN A IN PIGS, γ/1 cc.

Item compared	Age								
	Before nursing	1–12 hr. incl.	13–36 hr., incl.	37 hr.–7 day incl.	2nd–3rd wk.	4th–5th wk.	6th–7th wk.	8th–9th wk.	10th–11th wk.
Vitamin A	.10	.17	.14	.34	.26	.23	.17	.31	.20
No. of pigs	2	5	5	5	21	29	19	16	14

of .34 γ during the first week. Thereafter there was a gradual decrease through the sixth and seventh week. Eight- and nine-week-old pigs showed a higher level at which time the average vitamin A concentration exceeded .3 γ per 1 cc. of plasma. After weaning the vitamin A level decreased markedly, and fluctuated between .1 and .2 γ until the pigs were 4 months of age. Vitamin A values ranged from .04 to .60 γ/1 cc. blood plasma.

TABLE 2. NIACIN IN PIGS' BLOOD, γ/1 cc.

Item compared	Age							
	Before nursing	1–12 hr., incl.	13–36 hr., incl.	5th wk.	7th wk.	8th wk.	9th wk.	10th wk.
Niacin	8.3	8.4	7.6	6.8	6.2	6.8	6.5	5.2
No. of pigs	2	4	4	14	15	5	6	2

Table 2 shows the niacin content of pigs' blood for the period from birth to 10 weeks of age. The niacin values were found to be highest at birth and decreased gradually until reaching a constant figure of about 5 γ per cc. of blood after weaning. Unlike vitamins A and C, there was very little variation in the niacin content of pigs' blood. The values ranged from 2.5 to 8.9 γ per cc. whole blood.

No measurable amount of carotene could be detected in the blood plasma.

Nine pregnant sows were selected for vitamin A and C blood studies. They were bled shortly before farrowing (2 to 5 days) and again on the third day post partum. The results of this study are shown in table 3. Except for sow 838, parturition had very little effect on the plasma vitamin A and C. The average vitamin A value was identical before and after parturition. The vitamin C concentration dropped from .36 mg. to .27 mg., however, the

TABLE 3. VITAMIN C AND VITAMIN A CONTENT OF THE BLOOD PLASMA OF MATURE SWINE

Sow no.	Before farrowing		After farrowing	
	Vitamin C	Vitamin A	Vitamin C	Vitamin A
	mg./100 cc.	γ/1 cc.	mg./100 cc.	γ/1 cc.
838	1.09	.18	.25	.13
534	.29	.18	.24	.21
542	.28	.23	.34	.23
684	.14	.16	.06	.10
528	.46	.17	.24	.27
351	.09	.18	.18	.08
534	.24	.19	.40	.22
445	.34	.16	.39	.18
373	.34	.20	.30	.21
Average	.36	.18	.27	.18

large decrease in the case of sow 838 was largely responsible for this difference. Of the 9 sows, 5 decreased and 4 increased in plasma vitamin C following parturition.

There is very little information in the literature on the vitamin content of swine blood with which to compare these results. Nordfeldt (1944–45) reports a blood-serum level that ranged from .60 to .91 mg. vitamin C per 100 cc. in mature sows. Pigs from the same sows varied from .49 to .98 mg. vitamin C per 100 cc. of blood serum. Chu and Read (1938) found 3.83 mg. of vitamin C per 100 cc. of pigs' blood serum.

The fact that the vitamin C level was found to be higher in the newborn pig than it was in sows at parturition suggests a high placental transmission of vitamin C and accumulation of vitamin C in the fetus. There is also the possibility that the fetus is capable of synthesizing its own vitamin C. The vitamin C level in newborn pigs was found to be considerably higher than that reported by Lundquist and Phillips (1943) for the newborn calf, and as reported by Pope (1946) for the newborn lamb. An average of .96 mg. vitamin C per 100 cc. of plasma was found in the pig as compared to .70 mg. and .25 mg. respectively for calves and lambs. The vitamin C picture in young

pigs differs further from calves and lambs in that the vitamin C increases markedly instead of decreases after the intake of colostrum. Unpublished data from this Station show that sow's colostrum contains a high amount of vitamin C which might be responsible for the early increase of this vitamin in the pigs' blood. However, the plasma vitamin C in the pigs decreased more drastically after the first 3 days than did the vitamin C in the mother's milk. From this it can be postulated that in early life the pig is an efficient utilizer and/or synthesizer of vitamin C. It would be interesting to know the importance, if any, of this very high concentration of plasma vitamin C in the early life of the pig. The decline of plasma vitamin C from the second day to the sixth week coincides with the decline in vitamin C content of the sow's milk. The pigs used in these blood studies suffered from a digestive disturbance when they were 5 to 6 weeks of age, which might have affected the vitamin levels in the blood. If the decline of plasma vitamin C at 6 weeks and subsequent increase during the latter part of the suckling period is normal, the increase might be attributed to the intake of supplemental feed. It is possible that additional feed supplements the sow's milk enough with vitamin C and precursors to influence the blood level. The drop in vitamin C after the ninth week, which coincides with weaning, suggests that milk is a potent factor in determining the blood concentration of this vitamin. This work does not conflict with the work of Hughes (1928) and others who have shown that swine apparently synthesize their own vitamin C.

The vitamin A picture in young pigs is somewhat similar to that found by Lundquist and Phillips (1943) for calves, and Pope (1946) for lambs. The pigs were found to be low in vitamin A (.10 γ per 1 cc. of plasma) at birth. The rise in vitamin A, unlike vitamin C, was gradual and reached an average maximum of .34 γ between the second and seventh day. After the first week the pattern of the vitamin A curve was very similar to that of the vitamin C, and the same reasoning might be used to explain its behavior. Both vitamins C and A varied considerably among pigs and even in the same pig from one day to the next. No relationship between A and C could be established within the same individuals. Carotene in a measurable quantity could not be detected, thus suggesting that swine are very efficient converters of carotene to vitamin A.

Summary

1. Pigs are born with a relatively high plasma vitamin C level (.96 mg./100 cc.) as compared to that of calves and lambs.

2. Pigs are born with a relatively low plasma vitamin A level (.1 γ/1 cc.)

3. Both vitamin A and C concentrations increase after birth with a much sharper rise in C than A.

4. After the first week there is a general decline in the plasma A and C levels until the sixth week. This decline is followed by a rise until the time of weaning, when a more drastic drop occurs.

5. Niacin values show less fluctuation than do vitamins A and C. There is a gradual decline in the niacin level from birth until after weaning.

6. Vitamin A and C values for mature pregnant sows are quite different from those of newborn pigs, but similar to those of weanling pigs.

7. There is no measurable amount of carotene in swine blood.

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RELATIONSHIP OF TRYPTOPHANE TO NICOTINIC ACID IN THE FEEDING OF GROWING PIGS

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As an outgrowth of work on the pellagragenic effect of corn, Krehl and associates (1945) reported the interchangeability of tryptophane and nicotinic acid in preventing this effect in rats receiving a low protein diet. Woolley (1946) suggested that the effect of corn is exerted by reason of its content of 3-acetylpyridine, the pellagragenic effect of which is corrected by either nicotinic acid or tryptophane; while Kodicek and associates (1946) suggest that indole-3-acetic acid is the responsible constituent. Meanwhile Briggs (1945) has reported the interchangeability of nicotinic acid and tryptophane in preventing nicotinic acid deficiency in chicks receiving a purified diet low in nicotinic acid and tryptophane but containing no corn. Both Rosen and associates (1946) and Singal and associates (1946) have noted that addition of tryptophane to a diet deficient in nicotinic acid increased the urinary though not the fecal excretion of nicotinic acid in rats. These and other contributions leave little doubt that tryptophane and nicotinic acid can function interchangeably in the species dealt with and under the conditions obtaining.

More recently Luecke and associates (1947) have reported the production of nicotinic acid deficiency in pigs receiving a diet composed principally of corn and the prevention of most of the deficiency symptoms by the addition of tryptophane. The present paper reports an experiment, already concluded when the paper by Luecke and associates was published, which in many respects parallels their work and confirms their findings.

Experimental

In this experiment, six groups of five pigs each, balanced as to litters rep resented and to group weights, were employed. The litters varied in age from 35 to 48 days at the beginning of the experiment; individual pigs varied in weight between 7.5 and 13.0 kilograms; and the group weights varied from 47.05 to 48.3 kilograms. The pigs were fed for a period of six weeks.

Two basal diets of medium and lowered tryptophane content were employed, which were formulated as shown at top of following page. These diets will also be distinguished as the "casein diet" and the "gelatine diet" respectively. They were fed to the appropriate groups in the amount of 4 percent of their body weight per day so far as the appetite of the pigs permitted, although because of impaired appetite it became necessary in case of two groups showing deficiency symptoms to reduce the level to 3 per-

Constituent		(Medium tryptophane)	(Low tryptophane)
Corn,	percent	40.00	40.00
Purified casein,	"	20.72	13.81
Gelatine,	"	—	6.91
Dextrine,	"	26.90	26.90
Agar,	"	1.14	1.14
Salt mixture,	"	2.98	2.98
Lard,	"	8.28	8.28
Protein, (N×6.25)	percent	21.53	21.64
Nicotinic acid, mg./kg/d.,	"	.34	.36

cent during the last three weeks of the experiment. Fed separately, but considered as part of the basal diets, were adequate supplements of thiamine, riboflavin, pyridoxine, calcium pantothenate, choline, cod liver oil, and alpha tocopherol.

The several groups, numbered consecutively, were fed as follows: (1) casein diet only, (2) casein diet plus nicotinic acid, (3) gelatine diet only, (4) gelatine diet plus nicotinic acid, (5) gelatine diet plus d-l-tryptophane, (6) gelatine diet plus nicotinic acid plus d-l-tryptophane. The nicotinic acid when used was supplied at a level to provide 5 mg. per kilogram of live weight per day, while the tryptophane was incorporated into the diet at the rate of 0.25 gm. per 100 gm. of diet, which was equivalent to 1.81 percent of the gelatine contained therein. Relatively, the tryptophane intake was low for groups 3 and 4, medium for groups 1 and 2, and high for groups 5 and 6; while the nicotinic acid intake was low for groups 1, 3, and 5, and quite high for groups 2, 4, and 6.

Daily observations of the pigs were made on working days for evidences of impaired appetite and diarrhea; but as the pigs were penned and fed collectively as groups, no accurate account could be taken of the condition of the individual pigs within a group in respect to these observations. The individual pigs, however, were weighed at weekly intervals and the gain in weight of each pig was expressed in terms of percentage of its initial weight. Feeding was continued for six weeks, at the end of which period each pig was killed and subjected to post mortem examination with particular reference to necrotic lesions of the cecum and colon.

Results

The performance of the several groups at the end of six weeks is summarized in table 1, while statistical analysis of the growth data to the end of the third week and the end of the sixth week of the experiment leads to the results summarized in table 2.

From the comparisons in table 2 it is evident that as measured by growth

TABLE 1. SUMMARY OF PERFORMANCE OF GROUPS AT END OF EXPERIMENT

Items observed	Group number and diet fed*					
	1 C. Medium Tr., low NA.	2 C.+NA. Medium Tr., high NA.	3 G. Low Tr., low NA.	4 G.+NA. Low Tr., high NA.	5 G.+Tr. High Tr., low NA.	6 G.+NA. +Tr. High Tr., high NA.
Mean gain as percent of initial weight	36.9	133.0	28.0	82.8	112.3	108.8
Frequency of impaired appetite as percent of total days	65.3	6.9	84.0	18.1	0.7	2.1
Frequency of diarrhea as percent of total days	65.3	3.5	73.6	4.9	33.3	10.4
Mortality	0	0	0	0	0	0
Necrotic lesions, no. of pigs	2	0	2	0	0	0

* C. = casein diet; G. = gelatine diet; NA. = nicotinic acid; and Tr. = d-l-tryptophane.

both the casein and the gelatine diets were improved in highly significant fashion by the addition of nicotinic acid and that the effect was pronounced by the end of the third week. The same was true of the addition of tryptophane to the gelatine diet. Also, the addition of tryptophane to the gelatine diet produced a greater effect by the end of six weeks than did nicotinic acid, the difference being barely below that generally accepted as statistically significant. Nicotinic acid, however, produced no effect in the presence of high tryptophane, while the tryptophane produced an increase of rather questionable import in the presence of high nicotinic acid. It thus appears, as measured by growth, that tryptophane was effective in overcoming the nicotinic acid deficiency as well as the tryptophane deficiency of the gelatine diet, but that nicotinic acid was probably not fully effective in overcoming the tryptophane deficiency of this diet. Since this diet provided .36 mg. of nicotinic acid per kilogram of live weight per day, the experiment provides no measure of the ability of tryptophane to take over all the functions of nicotinic acid.

There remains the question of possible deficiencies of the gelatine diet in respect to amino acids other than tryptophane. It is quite evident that the gelatine diet enriched with nicotinic acid was inferior to the casein diet similarly enriched, but this presumably resulted largely from the tryptophane

TABLE 2. COMPARISON OF EFFECTS OF DIETARY TREATMENTS ON GROWTH

Effect studied	Groups compared	Mean differences in growth percent and their significance: at end of 3rd week	at end of 6th week
Nicotinic acid—			
with low troptophane	3–4	−12.72*	−54.84**
with medium tryptophane	1–2	−19.40**	−96.84**
with high tryptophane	5–6	5.40	4.28
Tryptophane—			
with low nicot. acid	3–5	−22.04**	−84.32**
with high nicot. acid	4–6	− 3.92	−25.20 (P=.097)
Tryptophane vs. nicot. acid with gelatine	4–5	− 9.32	−29.48 (P=.0508)
Casein vs. gelatine diets—			
with low nicot. acid	1–3	11.28*	8.96
with high nicot. acid	2–4	17.96**	50.18**
Casein diet+nicot. acid vs. gelatine diet+tryptophane	2–5	8.64	20.70 (P=.167)

* Difference significant, P = .05 – .01.
** Difference highly significant, P = .01 or less.

deficiency of the former, which the nicotinic acid was unable fully to correct. The difference between the growth rate obtained with the casein diet plus nicotinic acid and that obtained with the gelatine diet plus tryptophane, however, would be expected by chance once in six times, and cannot be viewed as significant. For the purposes of this experiment it appears unlikely that relative deficiencies of other amino acids, if any, had any material bearing on the results obtained.

The data on symptoms, mortality, and lesions found at autopsy, summarized in table 1, are not amenable to statistical analysis, but are in general accord with the implications of the growth data except in one particular. The diarrhea observed among the deficient animals of group 3 seemed to be almost completely prevented in group 4 by the feeding of nicotinic acid, but only partly prevented in group 5 by the feeding of tryptophane. The significance of this difference is not clear.

Summary

The results of the experiment reported in this paper may be summarized as follows:

1. A deficiency overcome by nicotinic acid was produced in pigs receiving a diet containing 40 percent of corn supplemented with casein and other purified materials to obtain a protein content of 21.5 percent by analysis and further supplemented with essential vitamins other than nicotinic acid.

2. The deficiency produced by a similar diet of lower tryptophane content was partly but apparently not completely prevented by additions of nicotinic acid.

3. The deficiency produced by the low nicotinic acid, low-tryptophane diet, except for some diarrhea, was prevented by the addition of d-l-tryptophane at the rate of .25 percent of the diet.

4. Nicotinic acid appeared not to be completely effective as a substitute for tryptophane, but tryptophane appeared to be, in large measure at least, a satisfactory substitute for nicotinic acid. More cannot be said, since the corn in the diet to which tryptophane was added supplied the experimental animals with about .35 mg. of nicotinic acid per kilogram of live weight per day.

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GENETICAL RESEARCHES ON THE NUMBER OF VERTEBRAE IN THE PIG

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AT THE pig breeding station of the Agricultural College of Norway the genetics of the number of vertebrae in the pig has been investigated by X-raying the young pigs within a week after farrowing. All pictures were taken on X-ray paper, the counting was done on the paper and all pictures were filed for checking.

The object was to investigate the variation in vertebrae number and to estimate the heritability of the variations. The breeding animals were selected for a high number of vertebrae in order to get longer pigs. The carcasses were measured after slaughtering. The measuring was done according to the rules which are used in the Danish bacon production. This article presents a summary concerning the inheritance. A more complete account is given in the Norwegian language in report number 22 from this institute.

The number of vertebrae was found to be an important factor in determining the length of the carcass. The length of the carcass increased as the number of vertebrae increased.

The number of vertebrae was counted from the head to *Os sacrum* and included the cervical, thoracic and lumbar vertebrae, The number of cervical vertebrae was seven in all pigs with a single exception—a pig which had only five. The variation was in the number of thoracic and lumbar vertebrae. In a few cases *Articulatio sacroiliaca* involved the last lumbar vertebra and first vertebra of *Os sacrum*. In these cases the last lumbar vertebra was counted as part of *Os sacrum* if *Facies auricularis* could be found on it. This checking had to be done after slaughtering.

No difference of any importance was found between the sexes. Two breeds of pigs, the Large White and the Norwegian Landrace, and some crosses between them are included. The difference between the average number of vertebrae was small but the Landrace had the largest variance both between litters and within litters, presumably because of being more heterozygous.

How selection for a higher number of vertebrae changed the average of the pigs born in each year will be seen from table 1. The total increase in vertebrae in the eight-year period was 0.88. The decrease in 1941 was caused by a single boar which himself had 29 presacral vertebrae, but transmitted as though he possessed a lower number. The individual presacral vertebrae numbers ranged only from 27 to 30. The increase in the average as a result of the selection, indicates that most of the variation was hereditary.

TABLE 1. PRESACRAL VERTEBRAE IN PIGS FARROWED FROM JAN. 1, 1933 TO DEC. 31, 1941. BOTH LIVEBORN AND STILLBORN PIGS ARE INCLUDED

Year	Number of pigs	Vertebrae				Average
		27	28	28	30	
1933	414	68	260	86	—	28.04
1934	603	71	375	157	—	28.14
1935	797	39	482	274	2	28.30
1936	682	29	257	387	9	28.55
1937	516	2	172	333	9	28.68
1938	583	2	152	391	38	28.80
1939	690	4	165	466	55	28.83
1940	381	—	29	304	48	29.05
1941	262	2	43	190	27	28.92
Total or Average	4,928	217	1,935	2,588	188	28.56

The number of ribs in each pig was counted. That number is the same as the number of thoracic vertebrae. The number ranged from 14 to 17. In 8.6 percent of the cases the last pair of ribs were rudimentary. These rudimentary ribs varied from a short piece of bone on one or both sides to nearly fully developed ribs on both sides. In some cases a fully developed rib was found only on one side, while the other side had none. The correlation between presacral vertebrae and ribs was rather high ($r = .782$).

Table 2 shows the distribution of presacral vertebrae and ribs. Rudimentary ribs are marked by a +. In the calculation they were given a value

TABLE 2. THE DISTRIBUTION OF PRESACRAL VERTEBRAE AND RIBS. RUDIMENTARY RIBS ON ONE OR BOTH SIDES ARE MARKED WITH A +. LIVEBORN AND STILLBORN PIGS FROM 476 LITTERS ARE INCLUDED

Vertebrae	Ribs								Ribs Ave.	Lumbar Vert. Ave.
	14	14+	15	15+	16	16+	17	Sum		
27	176	20	21					217	14.1	5.9
28	263	116	1,487	45	24			1,935	14.9	6.1
29		1	586	216	1,777	5	3	2,588	15.7	6.3
30					134	19	35	188	16.2	6.8
Sum	439	137	2,094	261	1,935	24	38	4,928	—	—
Average number of Presacral vertebrae	27.6	27.9	28.3	28.8	29.1	29.8	29.9	28.6	15.3	6.2
Lumber vertebrae	6.6	6.4	6.3	6.3	6.1	6.3	5.9	6.2	—	—

of 0.5 although an examination showed the genetical value of rudimentary ribs was nearly equal to fully developed ribs. From the table it will be seen that the correlation is strong and the regression is linear. The regression coefficient of ribs on vertebrae was 0.799. As the coefficient was lower than 1.00, the number of lumbar vertebrae decreases somewhat with the increasing number of ribs, but increases with increasing number of presacral vertebrae.

All matings were grouped according to the number of presacral vertebrae. The number of offspring, the average and the standard deviation of vertebrae are given in table 3. As the inheritance and manifestation were alike in the two sexes, the reciprocal matings are combined.

TABLE 3. THE INHERITANCE OF PRESACRAL VERTEBRAE IN PIGS

Parents	Offspring		
	n	Average	s
27X27	87	27.32	0.467
27X28	173	27.77	0.494
27X29	163	28.08	0.542
27X30	20	28.10	0.436
28X28	355	28.03	0.386
28X29	1,568	28.45	0.532
28X30	75	28.95	0.396
29X29	1,860	28.83	0.436
29X30	451	29.16	0.550
30X30	32	29.56	0.496

From the table it will be seen that heredity is the important factor in determining variation. The inheritance is additive and there is no clear dominance. The standard deviation has nearly the same value in all matings, but the lowest is found in matings of like phenotypes.

Matings of parents with low numbers give offspring averaging above the parents, and matings of parents with high numbers give offspring averaging below the parents. Apparently it is a case of intermediate heredity and an unknown number of factors, with a rather large part of the variance being determined by hereditary factors.

By calculating the average of each parent's offspring, animals with the same phenotype were found to vary widely in their genotypic values. Part of this variation was associated with the number of ribs. Among animals with the same number of vertebrae the highest genotypic value was found in those animals with the highest number of ribs.

The breeding animals were selected for a larger number of vertebrae. As fewer boars than sows are needed, a stronger selection of boars could be

TABLE 4. DISTRIBUTION OF THE BREEDING ANIMALS' PRESACRAL VERTEBRAE AND RIBS

Vertebrae	Ribs							Sum
	14	14+	15	15+	16	16+	17	
Sows								
27	8	2						10
28	8	6	41	1				56
29			21	11	48	1		81
30					10			10
Sum	16	8	62	12	58	1		157
Average 28.58				15.29				
Boars								
27	2							2
28		2	4					6
29			8	2	17			27
30					3		1	4
Sum	2	2	12	2	20		1	39
Average 28.85				15.51				

made. The average difference between them was not large, as will be seen from table 4.

As the inheritance appeared to be intermediate and the number of factors were unknown, the correlation and regression between parents and offspring were calculated in order to learn how closely the phenotype of an

TABLE 5. CORRELATION BETWEEN PARENTS AND OFFSPRING WHEN BOTH PARENTS HAD THE SAME NUMBER OF PRESACRAL VERTEBRAE: $r = .682$; $E_y = 6.410 + .773x$; $E_x = 11.542 + .602y$

Offspring (y)	Parents (x)				Sum	Average (x)
	27×27	28×28	29×29	30×30		
27	59	20	3		82	27.32
28	28	303	350		681	28.47
29		32	1,463	14	1,509	28.99
30			44	18	62	29.29
Sum	87	355	1,860	32	2,334	28.79
Average y	27.32	28.03	28.83	29.56	28.66	—

offspring could be predicted from the phenotype of its parents. The correlation between parents and offspring when both parents had the same phenotype is given in table 5.

The matings of parents phenotypically alike resulted in offspring which on the average showed a strictly linear regression. When the vertebrae number increased in both parents by *one* vertebra, the offspring increased on the average 0.773.

As the inheritance was apparently intermediate the correlation between mid-parent and offspring was calculated. Matings of 27×28 were grouped as 27.5, 27×29 as 28 etc. The results are given in table 6.

TABLE 6. CORRELATION BETWEEN THE PHENOTYPIC AVERAGE OF THE PARENTS AND THE OFFSPRING'S PHENOTYPE:
$r = .629$; $E_y = 7.276 + .743x$; $E_x = 13.450 + .533y$

Offspring (y)	Average of parents (x)							Sum	Average (x)
	27.0	27.5	28.0	28.5	29.0	29.5	30.0		
27	59	45	38	23	3			168	27.60
28	28	122	418	840	358	37		1,803	28.41
29		6	62	719	1,526	302	14	2,629	28.90
30				6	48	112	18	184	29.39
Sum	87	173	518	1,588	1,935	451	32	4,784	28.69
Average	27.32	27.77	28.05	28.45	28.84	29.16	29.56	28.59	—

The regression was slightly lower than in table 5, but the regression coefficient was still .743. As the variance of the offspring naturally was greater than that of the parents (which were partly selected for vertebrae number) the regression of parents on offspring was lower. This .743 is a direct estimate of heritability of individual differences in vertebrae number in this population. It would be raised to .803 if Sheppard's correction for coarseness of grouping were made. (Vertebrae phenotypic number is confined to four classes but genotypic values probably are not restricted to whole numbers.) Even such a high heritability still leaves considerable room for incomplete penetrance, embryological accidents, etc., to make phenotype different from genotype.

Usually there is a rather strong correlation between the parents in a breeding experiment with selection being practiced for some character and the regression coefficient found is not representative for either parent alone, as it combines the effect of both of them.

In this experiment the correlation between mates was rather strong, as will be seen from table 7.

TABLE 7. CORRELATION AND REGRESSION BETWEEN DAMS AND SIRES. EACH PAIR OF PARENTS IS ENTERED AS MANY TIMES AS THEY HAD OFFSPRING: $r = .301$; $b_{z.x} = .274$; $b_{x.z} = .322$

Sires (z)	Dams (x)					Average (x)
	27	28	29	30	Sum	
27	87	120	40		247	27.81
28	53	355	186	30	624	28.31
29	123	1,382	1,860	185	3,550	28.59
30	20	45	266	32	363	28.85
Sum	283	1,902	2,352	247	4,784	28.54
Average	28.27	28.71	29.00	29.01	28.84	—

The correlation was .301 which was large enough to have considerable influence on the regression found between dams and offspring and on that between sires and offspring. The time trend shown in table 1 contributes much to this correlation. The regression of offspring on sires was .492 and of offspring on dams was .479. This high value combines the effect of one of the parents and part of that of the other.

Summary

The variation of the number of vertebrae in pigs is inherited. Heritability seems to be about .74 (table 6). The type of inheritance is intermediate. The number of the factors is not known. The number of ribs increases with increasing number of presacral vertebrae. With increasing number of ribs the number of lumbar vertebrae decreases.

Rudimentary ribs when present have about the same genetical value as fully developed ribs.

When the breeding animals are selected, the correlation between parents with respect to the selected character will render the regression coefficient on either parent too high to represent the influence of that parent alone.

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COBALT TOXICITY IN CALVES RESULTING FROM HIGH ORAL ADMINISTRATION[1]

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THE widespread recognition of cobalt deficiency diseases in ruminants during the past few years has stimulated investigations of cobalt metabolism. Prophylactic and therapeutic doses of cobalt have been recommended by workers in the various areas of reported deficiency. However, the ease and likelihood of administering many times the requirement of cobalt makes a knowledge of the toxic level and of factors affecting cobalt toxicity in ruminants of prime importance.

It was the object of this study to investigate the approximate level of cobalt that will produce toxic symptoms in dairy calves and some of the factors affecting the toxicity of orally administered cobalt.

Comparison of Various Cobalt Salts

Four calves 120 to 200 days of age which were fed a daily ration of 10 pounds of whole milk and two to three pounds of a mixture consisting of two parts of ground corn and one part of chopped alfalfa were used in this study. Three of these animals were fed 500 mg. of elemental cobalt as the chloride, sulfate or carbonate for thirty days, while the fourth calf was used as a control. These animals receiving the cobalt dosage ate very little grain after five days. However, they continued to drink milk during the experimental period. The animals receiving the cobalt salts lost weight and manifested the symptoms of cobalt deficiency while the control animal continued to gain at a uniform rate. With this limited number of animals we were unable to detect polycythemia or changes in total blood volume. However, additional data are needed to substantiate these results.

Effect of Level of Dietary Protein

Several workers (Griffith *et al.*, 1942; Josland, 1936; Josland and McNaught, 1938; Smith, 1943; Stare and Elvehjem, 1933) have reported the toxic effect of dietary cobalt in the rat. Griffith, Pavcek and Mulford (1942) found 0.12 percent dietary cobaltous sulfate was toxic to rats fed diets containing 12, 18 and 30 percent casein.

Other workers (Burk *et al.*, 1946; Kondo and Hayashi, 1928; Michaelis, 1929; Michaelis and Yamaguchi, 1929; Schubert, 1931; Schubert, 1933) have reported that cobalt forms coordination complexes with certain amino acids

[1] Published with the approval of the Director of the Michigan Agricultural Experiment Station, East Lansing, Michigan as Journal Article 902 (n.s.).

TABLE 1. COMPOSITION OF RATIONS

Constituent	Ration I	Ration II
Ground corn	50%	40%
Ground barley	50%	40%
Casein	—	20%
Crude protein*	10.6 %	24.75%
Methionine**	0.28%	0.778%

* Values from Schneider (1947).
** Values from Almquist (1946).

which suggests that these compounds may have reduced toxic effects in the body.

Griffith *et al.* (1942) reported that the injurious character of cobalt containing food mixtures is decreased by the administration of methionine, cystine or cysteine. Burk *et al.* (1946) found that tolerance doses of cobalt for mice could be raised many fold by concurrent injections of histidine. Dunn *et al.* (1947) observed reduced toxic symptoms when intravenous methionine was given prior to the intravenous injection of cobalt to calves. This sug-

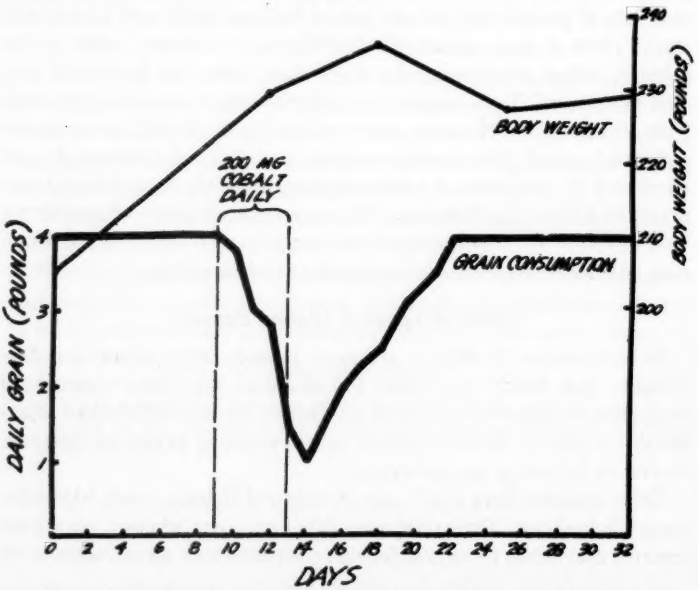

Figure 1. Effect of 200 mg. of cobalt daily on body weight and grain consumption of calves receiving ration I. (Average of four animals.)

gests that variation of certain amino acid intakes due to differences in level of dietary protein or variation in protein quality might be an important factor in reducing the toxicity of cobalt.

It was the object of this experiment to study the effect of adding casein to the grain ration on the toxicity of cobalt fed to calves. Four calves were placed on ration I and four on ration II, the ingredients of which are shown in table 1.

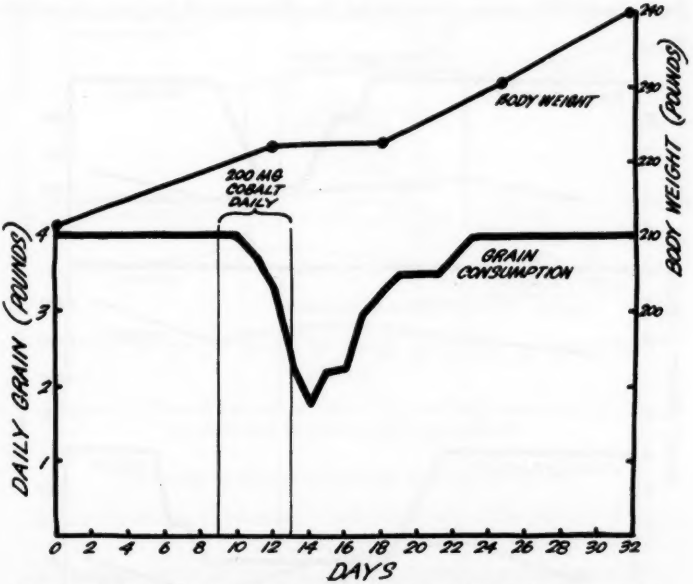
BODY WEIGHT
200 MG COBALT DAILY
GRAIN CONSUMPTION
DAILY GRAIN (POUNDS)
BODY WEIGHT (POUNDS)
DAYS
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32
1 2 3 4
200 210 220 230 240

Figure 2. Effect of 200 mg. of cobalt daily on body weight and grain consumption of calves receiving ration II. (Average of four animals.)

After ten days on these rations, cobalt sulfate solution containing 200 mg. of elemental cobalt was administered daily for four days. Figure 1 shows the average body weight and average grain consumption of the four calves receiving the low protein grain ration. The grain consumption dropped markedly during the cobalt administration period and did not return to normal for several days after it was discontinued.

Figure 2 shows the average body weight and average grain consumption of the four animals receiving the high protein grain ration. The average grain consumption dropped off very similarly to those on the low protein grain. A comparison of the average body weight of the animals in each group indicates that the cobalt administration had less effect on growth of the

calves on grain ration II. There was less depression of growth rate in this group and an earlier return to normal gains in body weight after discontinuing cobalt treatment.

In view of the fact that the dosage given to the animals described above was considerably in excess of the required dosage for producing toxic symptoms, three calves each were placed on ration I and ration II respectively and fed 100 mg. of elemental cobalt as cobalt sulfate for ten days as shown in figures 3 and 4 respectively. A comparison of the grain consump-

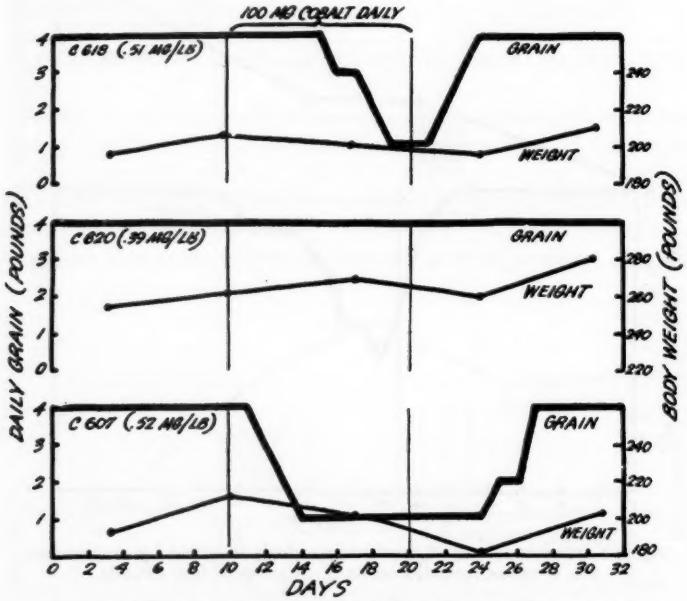

Figure 3. Effect of 100 mg. of cobalt daily on body weight and grain consumption of calves receiving ration I.

tion of the individual animals in these two groups shows some individual variation in response to the same cobalt intake.

Under the conditions of this experiment, no effect on the toxicity of cobalt can be ascribed to changing the protein content of the grain ration by adding casein to a simple grain mixture. In both groups the greatest depression of growth occurs in the animals showing the greater effect on appetite. Toxic effects other than loss of appetite are indicated in animal C620 as shown by a depression of growth without loss of appetite.

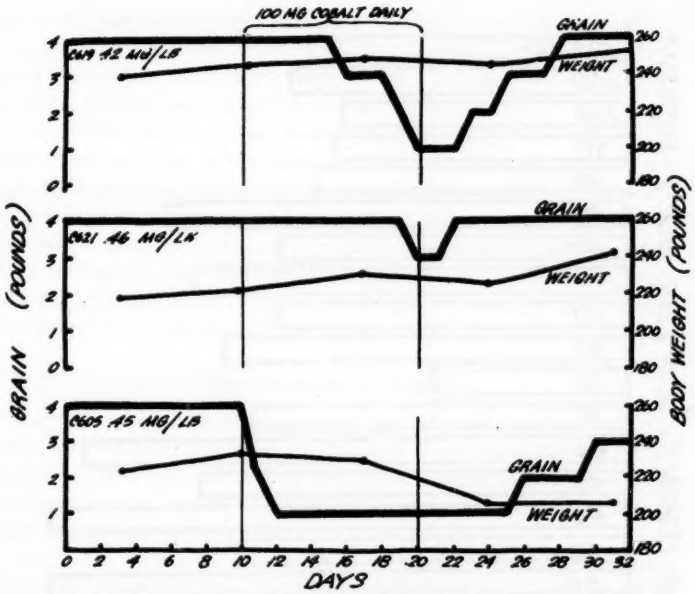

Figure 4. Effect of 100 mg. of cobalt daily on body weight and grain consumption of calves receiving ration II.

Toxicity of Various Dosage Levels of Cobalt

During the course of this study, trials were made of the toxicity of various dosage levels of elemental cobalt, as cobalt sulfate, to growing dairy calves weighing from 186 to 325 pounds. Figure 5 shows the percentage grain consumption of calves during the experimental period, based on the percent of that consumed during a pre-experimental control period of ten days while administering dosages of cobalt ranging from 35 to 108 mg. per 100 pounds body weight. The dosage indicated was administered for periods of from four to sixteen days with the exception of three animals receiving dosages of 35, 39, and 45 mg. These dosages were continued for 21, 13 and 21 days respectively.

The data in figure 5 indicate that oral dosages of elemental cobalt lower than 40 mg. per 100 pounds of body weight for the length of time reported are not toxic from the standpoint of reduced appetite when fed to calves under the conditions described.

Dosage levels between 40 and 50 mg. per 100 pounds of body weight, however, give variable results due to physiological differences of the in-

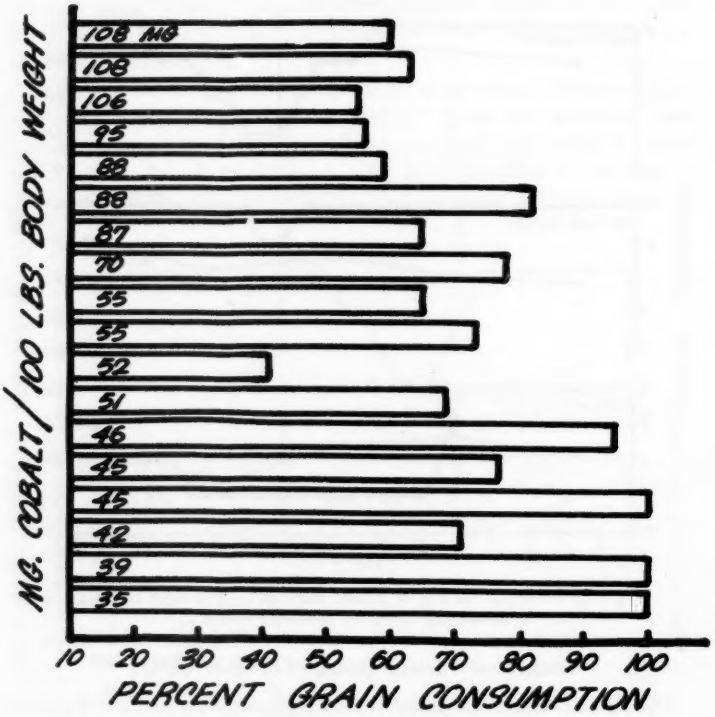

Figure 5. Effect of various levels of cobalt feeding on the grain consumption of individual calves.

dividual animals. Dosage levels above 50 mg. per 100 pounds of body weight had a detrimental effect on appetite for grain in all cases. While there is considerable variation in the length of time for depressed appetite to occur in the animals receiving the lower dosages, all of the animals receiving 80 mg. or more of elemental cobalt per 100 pounds of body weight showed reduced appetites in three days or less.

This toxic level in calves is considerably less than that apparently required per unit of body weight for production of toxic effects in the rat. Stare and Elvehjem (1933) observed toxic effects with young rats (28 to 42 gms.) receiving more than 0.6 mg. of cobalt per day. Feeding 1.0 and 1.5 mg. of cobalt per day caused a rapid loss of weight and 2.0 mg. per day caused death in two weeks. Smith (1943) found 200 p.p.m. of cobalt in the ration of rats produced toxic effects resulting in small consumption and decreased growth,

but growth was resumed when the cobalt was discontinued. Addition of 500 p.p.m. produced death in young rats in 3 to 5 weeks. The above levels of cobalt feeding are in the same range as the injurious levels reported by Josland (1936) and Josland and McNaught (1938).

Unpublished results at this station (Huffman, 1945) have shown that wide variations occur in the tolerance of individual animals to relatively high doses of cobalt, indicating that physiological condition of the animal may play an important role in establishing the toxic level. For instance, detrimental effects to appetite have occurred in lactating animals with single doses of from one to five grams of cobalt sulfate, while two young bulls have tolerated daily doses of ten grams of cobalt sulfate for 90 and 127 days respectively before showing extreme emaciation.

Interpretation of Results

Previous reports have indicated that increasing the dietary amino acid intake by increased protein levels in the feed is ineffective in reducing the toxicity of orally ingested cobalt to the rat. In contrast, certain amino acids have been shown to be effective in reducing the toxicity of cobalt when injected intraperitoneally into rats and intravenously in calves.

Our results with calves fed toxic levels of cobalt indicate that increasing the dietary intake of protein does not reduce the toxicity as measured by reduced appetite. On the 200 mg. daily dose of cobalt, however, the calves showed less effect on rate of gain in body weight on the higher protein grain than those receiving the low protein grain. When two groups of calves were placed near the minimum toxic level of cobalt (42 to 52 mg. per 100 pounds of body weight) there was still no decrease in the toxicity of cobalt in the calves receiving the 24 percent protein grain. This indicates that certain amino acids are not available, or not effective, in forming complexes in the digestive tract that reduce the toxicity of cobalt.

There is some indication that excessive cobalt administered orally has a detrimental effect before the observance of reduced appetite occurs in calves.

Under the experimental conditions used, oral administration of 40 mg. or more of cobalt daily per 100 pounds of body weight produced toxic effects in dairy calves. This is in agreement with the tolerance level reported by Keener *et al.* (1947).

Summary

Equivalent amounts of cobalt fed as the sulfate, chloride or carbonate were equally toxic to the dairy calf.

Cobalt fed in excess of 40 mg. daily per 100 pounds of body weight produced toxic effects in dairy calves.

Increasing the methionine content of the grain ration by addition of casein did not reduce the toxicity of cobalt fed to dairy calves.

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THE FERTILITY OF BOVINE SPERMATOZOA TREATED WITH IMMUNE SERA FOR THE CONTROL OF TRICHOMONIASIS[1]

BANNER BILL MORGAN
University of Wisconsin[2]

BOVINE trichomoniasis has long been known to be transmitted in nature by coitus, from the bull to the cow, or vice versa. This venereal disease of cattle causes reproductive disturbances due to the invasion of *Trichomonas foetus* into the vagina and uterus. Early abortion, repeated breedings, purulent discharges and delayed conceptions are some of the symptoms of this disease. In the bull, some of the symptoms include inflammation of the prepuce; in chronic cases the organisms may invade the upper reproductive tract.

The spread of trichomoniasis can be prevented by eliminating infected bulls, breeding rest of infected cows and introduction of artificial insemination. The disease can be transmitted by artificial insemination if semen from an infected bull is used. This was demonstrated by Garlick (1939) and Bartlett *et al.* (1947).

Since the motility of spermatozoa of infected bulls is seldom impaired by trichomoniasis and some cows become immune, herd owners are sometimes reluctant to slaughter infected bulls. This suggested attempts to salvage valuable animals either by medicinal treatment of the bull (Bartlett, 1946; Morgan, 1947) or manipulation of semen to destroy the trichomonads.

During the course of prior immunological investigations on *Trichomonas foetus* it was observed that cows injected intramuscularly or intravenously, with motile organisms over a long period of time, produced rather potent immune sera. Low dilution of serum admixed with a standard antigen of living trichomonads caused immediate immobilization of the flagellates. This phenomenon has been described in detail by Robertson (1941) and Morgan (1943). The organisms were apparently killed since motility was never regained after immediate transfer to culture media and subsequent incubation.

Further observations by Morgan (1944) demonstrated that raw bovine sera would lyse *T. foetus* in low dilutions. The lytic property was destroyed temporarily by heating the sera at 56° C. for 30 minutes.

Morgan and Campbell (1946) tested 350 compounds to determine their effect on *T. foetus*. Thirty of the drugs were tested in combination with bovine semen. Dilutions which killed *T. foetus* were also lethal to the

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spermatozoa. Bottcher's (1939) attempts to kill trichomonads in semen with six different chemicals were also unsuccessful.

The purpose of this paper is to present the results of experimental treatment of bovine semen containing *Trichomonas foetus* with both raw and hyper-immune sera and prior to use for artificial insemination of heifers and cows. Samples of semen from two bulls were employed for inseminating 101 females over a period of years commencing in 1942.

Materials and Methods

Semen used in these studies was collected with the artificial vagina from a clinically normal bull with a good breeding record and from a trichomonad infected bull. The immune sera were obtained from 2 heifers and 2 pregnant cows previously injected with 5 ml. of washed bacteria-free trichomonads intramuscularly along the mid-neck about twice a week over a period of 3 months. *Trichomonas foetus* used in this work was a strain isolated by Morgan (1943). Raw serum was used the same day as drawn, otherwise the serum was heated at 56° C. for 30 minutes. Semen was diluted with two volumes of serum and immediately after mixing was inseminated into heifers or cows. The vaginal tracts of all of the animals were swabbed between the 14th and 19th day after insemination in order to detect any trichomonads which might be present. A part of the 101 clinically normal females used in this study were maintained in the Department of Veterinary Science experimental herd and part on cooperating farms located in Wisconsin. Twenty clinically normal cows bred artificially with clean semen and 20 clinically normal cows bred artificially with semen from a trichomonad infected bull served as controls.

Results and Discussion

The results are shown in table 1. Artificial insemination of 26 cows with semen from a normal bull to which 100,000 trichomonads were added prior to addition of 2 parts of normal raw bovine sera resulted in 5 pregnancies. These pregnancies terminated in parturition of normal calves. Similar material diluted with hyper-immune sera and inseminated into 25 cows also resulted in 5 normal calvings. Semen from a trichomonad infected bull treated in a like manner inseminated into two groups of 25 cows each resulted in 6 and 4 normal calvings, respectively. All of the animals remained continually negative for trichomoniasis. The artificial insemination of twenty control animals with normal undiluted semen resulted in 17 pregnancies. The 20 control heifers artificially inseminated with semen from a trichomonad infected bull resulted in four normal calvings; 16 cows developed trichomoniasis. Among the 101 animals inseminated a total of 20 pregnancies resulted, a percentage of 19.8.

TABLE 1. SUMMARY OF RESULTS ON THE ARTIFICIAL INSEMINATION OF 101 HEIFERS AND COWS WITH SEMEN DILUTED WITH RAW OR HYPER-IMMUNE BOVINE SERA (.5 ml. of semen to 1 ml. of serum) FOR THE CONTROL OF TRICHOMONIASIS

Type of semen	Dilution with normal raw sera	Number of cows artificial insemination (one insemination)	Number of cows calved from this insemination (one insemination)	Number of cows showing trichomonad infection	Dilution with hyper-immune sera	Number of cows artificial insemination) (one insemination)	Number of cows calved from this insemination (one insemination)	Number of cows showing trichomonad infection
Semen from normal bull 100,000 trichomonads added	1:2	26	5	0	1:2	25	5	0
Semen from trichomonad infected bull	1:2	25	6	0	1:2	25	4	0
Control; semen from normal bull	undiluted (1.5 ml.)	10	9	0	undiluted (1.5 ml.)	10	8	0
Control; semen from trichomonad infected bull	undiluted (1.5 ml.)	10	3	7	undiluted (1.5 ml.)	10	1	9

The results suggest very little promise in the treatment of infected semen with either raw or hyper-immune serum to destroy *Trichomonas foetus*. The serum from the pregnant animals had a more injurious effect on spermatozoa than open females. Agglutination and killing of the spermatozoa was produced within 2 to 5 minutes. Bernstein and Lazarew (1933) had previously reported that bull sperm were agglutinated by sera of both cows and bulls. Chang (1947) found that inactivated bovine serum mixed with bovine spermatozoa produced immediate lethal effects or inactivation of the spermatozoa within two hours. Unless the lethal effect of bovine serum for sperm can be overcome, this method for the control of bovine trichomoniasis and utilization of trichomonad infected bulls appears to be impractical. In the case where the value of animals is so great this method might be utilized to beget offspring.

Summary

One hundred and one cows and heifers were artificially inseminated with semen from a trichomonad infected bull and semen from a normal bull to which *Trichomonas foetus* had been added. The semen was diluted with raw or hyper-immune bovine sera for the purpose of inactivating or destroying the trichomonads. Twenty cows became pregnant and calved normally

(19.8%). Artificial insemination of twenty control animals with normal undiluted semen resulted in 17 pregnancies. Twenty control cows bred artificially with semen from an infected bull resulted in 4 normal calvings; 16 cows contracted trichomoniasis. This method cannot be placed on a practical basis until the spermaticidal effects of bovine sera can be removed.

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A SELF-SERVING SPRINKLING DEVICE FOR COOLING DAIRY CATTLE

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Louisiana Agricultural Experiment Station

That Louisiana dairy cows are rapidly cooled in summer when sprinkled with water has been amply proved (Seath and Miller, 1947, 1948). Recent work in India (Minett, 1947; Sinha and Minett, 1947) shows that sprinkling or splashing with water is essential to water buffaloes in hot weather. Sprinkling or natural rain also was found to lower the body temperature of zebu cattle, small hill cattle, and sheep.

Following a previous experiment (Seath and Miller, 1947) attempts were made to operate an ordinary garden hose and nozzle so that cows could voluntarily go into the spray for relief during the warm portions of summer days. Even though the spray was located in a shady spot of the paddock, it was found that the cows would not use the spray. The reason for this nonusage appeared to be the coarseness of the spray.

In a search for a mist-producing spray similar to those used on vegetable counters in grocery stores, a local dealer was found who was able to secure a type that appeared promising. The nozzle was merely labeled a "self-cleaning fog nozzle"[2] and was designed to permit adjustments to be made in the fineness of the spray produced.

Procedures

Two groups of grade Jerseys each consisting of 2 milking cows and 1 yearling heifer were used in this experiment. These animals were kept in a very small pasture lot that was divided into halves by an electric fence. Only one of these halves provided shade for the animals and that one had a shelter constructed from poles and bamboo branches. The shaded area thus provided was approximately 8′ × 12′ in size with the ceiling about 5½′ from the ground. From this ceiling was suspended a ½ inch water pipe to which were attached at regular intervals 4 self-cleaning mist-producing spray nozzles.

Tests to determine the amount of water used by the 4 sprinkling nozzles were made on 3 different days by suspending buckets from the ceiling where nozzles protruded from the water line. The results showed that nozzle No. 1 used 16.9, 19.0 and 18.1 pounds per hour, respectively, for the three days. For nozzle No. 2 it was 13.8, 14.5, and 14.8 pounds; for No. 3 14.4, 17.0, and

[1] Now in charge of Dairy Section, University of Kentucky, Lexington, Ky.

[2] This nozzle was secured from Geo. P. Walter, 735 N. 21st St., Baton Rouge, La. who cooperated with the manufacturer in making alterations necessary for use in this experiment. It was operated on a water pressure of approximately 40 pounds per square inch, but was designed to operate on pressures from 20 to 120 pounds with the best performances at the higher pressures.

16.7 pounds, and for No. 4, 18.0, 15.6, and 13.4 pounds. The average amount per hour was 16.0 pounds per nozzle and 64.1 pounds for all 4 nozzles.

Each nozzle produced an extremely fine spray which covered one-fourth or more of the shaded area. To prevent a mud hole from developing Portland cement and water were mixed with the top 4 inches of soil and then smoothed in order to produce a hard surface of sufficient durability to last more than long enough to complete the experiment. Mixed hay and grain were provided for the animals in amounts sufficient to care for body maintenance, growth, and milk production.

The treatment of the two groups of animals during 12 warm clear days selected for the experiment follows:

	Treatment for Groups	
Days	*Group A*	*Group B*
1, 5, 9	shade	sunshine
2, 6, 10	shade and sprinkled	sunshine
3, 7, 11	sunshine	shade
4, 8, 12	sunshine	shade and sprinkled

This design provided for one group to be in the sun each time that a group was allowed use of the shade alone or of shade with sprinkler in operation. Between 8:00 and 9:00 A.M. on test days the two groups of animals were turned loose in their respective lots so as to permit them free access to the treatment assigned to them for that day. Between 11:00 and 11:30 A.M. each animal was caught, tied with a halter, and records were secured concerning their respiration rates (from flank movements) and rectal body temperatures.

Results and Discussion

Atmospheric Conditions

Air temperatures as taken in the shade at 11:00 A.M. on test days (table 1) ranged from 87° to 94° F. with an average of 90.7° F. The relative humidity (table 1) taken at this same time as determined by a sling psychrometer ranged from 46 to 66 percent with an average of 58.8 percent. In general, it would appear that neither air temperature or relative humidity varied excessively between the test days selected. Air movement during the course of the experiment was recorded as "very little" on 4 days, "light" on 1 day, and "mild" on "moderate" breeze on 7 days, thus exhibiting no unusual variation.

Effect of Cooling on Milking Cows

As shown in the right portion of table 1, the cows that were in the shade either with or without sprinkler gave evidence on every test day of being much cooler than were cows of the second group in the sun without benefit

TABLE 1. HOW FREE ACCESS TO SHADE AND SHADE PLUS SPRINKLING AFFECT BODY TEMPERATURES AND RESPIRATION RATES OF JERSEY COWS

Days, 1947	Atmospheric records at 11 A.M.		Average body temperatures, °F.			Average respiration rates, (times per minute)		
	Temp., °F.	Humidity, percent	In Sun	In Shade	Shade+ sprinkler	In Sun	In Shade	Shade+ sprinkler
Aug. 26	87	66	102.55	101.75		93.0	83.0	
27	89	61	103.40		101.50	99.0		63.5
28	89	57	104.60	101.70		113.5	84.0	
29	89	65	105.00		100.75	115.5		52.0
30	92	59	103.45	102.20		96.5	89.0	
Sept. 1	94	46	103.90		100.50	107.0		51.0
2	90	65	104.65	101.75		117.5	86.5	
3	92	53	105.10		100.65	121.5		57.0
4	91	56	103.45	102.25		110.0	88.5	
5	90	61	103.65		100.35	116.5		63.5
6	92	59	104.85	101.85		124.5	80.0	
10	93	57	104.40		100.80	141.0		53.0
Average	90.7	58.8	104.08	101.91	100.76	113.0	85.2	56.7

of cooling treatments. Cows allowed use of shade alone averaged 101.91° F. in body temperature and 85.2 in respiration per minute as compared to 104.08° F. and 113 times per minute, respectively, for tests made in the sun. Free-choice use of the shade with sprinkler in operation, however, proved even more efficient in cooling the cows. In all cases the cows spent a major part of the time under the sprinkler and appeared to enjoy it. Under this treatment body temperatures of cows on all but one day were below 101° F., which is often quoted as being approximately normal. The average for all days was 100.76° F.

Respiration rates for individual test days (table 1) also show that shade plus sprinkling cooled cows more in every comparison than did shade alone. With shade and sprinkling the respirations averaged 56.7 times per minute or 28.5 times per minute slower than where shade alone was provided.

A comparison of the cooling for individual cows as shown in table 2 is of special interest, for although much variation is shown in body temperature of the cows while in the sun, with averages of 103.12 to 105.18° F., these comparisons after cooling with shade and sprinkling show relatively little variation, with averages of from 100.63 to 100.93° F. It is of special interest that the cow X5 cooled to an average of 100.93° F. when she averaged 105.18°

TABLE 2. AVERAGE REACTIONS OF INDIVIDUAL ANIMALS WHEN SUBJECTED TO COOLING TREATMENTS WITH CORRESPONDING DATA WHILE IN THE SUN

Milking cows	Average body temperatures, °F.			Average respiration rates, (times per minute)		
	In sun*	In shade	Shade+ sprinkler	In sun*	In shade	Shade+ sprinkler
X1	104.35	101.57	100.63	116.0	78.3	52.6
X5	105.18	102.57	100.93	128.5	95.3	66.0
X4	103.12	101.53	100.73	109.3	88.0	56.7
X7	103.75	101.97	100.73	98.0	79.0	51.3
Average	104.08	101.91	100.76	113.0	85.2	56.7
Heifers						
X10	103.12	102.30	101.70	118.2	95.0	67.7
X11	102.87	102.07	101.93	102.6	78.3	60.3
Average	102.99	102.18	101.82	110.4	86.7	64.0

* Average while in sun is for 6 records but all others are for only 3 separate test days.

F. while in the sun. To a lesser degree this same trend took place when cooling was measured by respiration rate.

Effect of Cooling on Heifers

It soon became apparent in the course of the experiment that two yearling heifers, one in each group, were responding differently from the cows to the cooling treatments. The sunshine without shade (table 2) failed to produce as high body temperatures, although respiration rates were almost as high as those for the cows. Body temperatures while in the sun averaged 102.99° F. as compared to 104.08° F. for the cows. Shade alone reduced these body temperatures of heifers to 102.18° F. and when allowed free access to shade and sprinkling the average was 101.82, or 1.06° F. higher than for the cows.

Observations revealed that the heifers did not use the shade or the shade with sprinkler as much as did the cows. It appeared that they were not suffering much from the hot weather and did not have as much desire to use the cooling treatments as did the cows. Also, each heifer was forced to compete with two cows that were older and larger and, as a result, they were afraid to crowd in and make liberal use of the shelter. The latter point appeared to be minor in importance, however, for a post experimental trial revealed that when the two heifers were left together without the cows they did not make liberal use of the shade and sprinkler.

Discussion

The cooling effects of the self-serving sprinkling device are highly encouraging. Body temperatures were reduced to levels below those secured in previous experiments (Seath and Miller, 1947, 1948) either by hand sprinkling alone or by hand sprinkling plus the use of a fan. That these temperatures were reduced to averages below the accepted normal of 101–101.5° F. was wholly unexpected. The continuous evaporation of water from the cows' bodies would probably explain the good results. In the previous experiments the cows were sprinkled by hand just once.

With hourly water usage averaging only 16 pounds per nozzle it would be within reason to utilize this method of cooling cows in hot weather where water pressure is available. Just how much this would help in producing greater milk and fat production, however, remains for further experimentation to demonstrate. It was obvious from the results of this experiment that cows made liberal use of the sprinkling device on warm days and, as a result, gave evidence that they suffered less from the hot weather. If the cooling effects tended to produce more milk and higher tests as reported in other experiments (Hays, 1926; Ragsdale and Turner, 1922; Regan and Richardson, 1938) then the sprinkling device described and tested in this experiment would have much practical application.

Summary

Body temperatures and respiration rates of cows were markedly lowered when cows were allowed free access to a mist-like spray in the shade. This occurred in an experiment conducted during late August and early September of 1947 when air temperatures in the shade, taken at 11:00 A.M., averaged 90.7° F. and relative humidity 58.8 percent.

Previous trials had demonstrated that the wetting of cows with water tended to cool them. However, it had been noted that the conventional hose nozzle produced a spray so coarse as to discourage cows from using it. In the present experiment several extremely fine mist-producing nozzles were attached to a water pipe suspended from the ceiling of a bamboo-constructed shade. The conditions produced proved to be especially inviting to milking Jersey cows, with a trend in this direction also for yearling Jersey heifers.

Comparative records kept on body temperatures of the 4 milk cows showed averages of 104.08° F. when in the sun, 101.91° F. when in the shade, and 100.76° F. when using shade with sprinkling device. Respiration rates averaged 113.0, 85.2, and 56.7 times per minute, respectively, under these three conditions. The sprinkling device tended to lower body temperatures and respiration rates to levels considered approximately normal for cool weather.

Two yearling heifers in this same experiment had body temperatures averaging 102.99° F. in the sun, 102.18° F. in the shade and 101.82° F. when allowed to use the shade with sprinkler. Respiration rates showed a similar trend with averages of 110.4, 86.7, and 64 under these respective conditions. In general, the heifers made use of the spray less than did the cows, apparently not feeling as much need for its cooling effect.

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NEWS AND NOTES

The Fortieth Annual Meeting of the American Society of Animal Production will be held at the Hotel Sherman in Chicago, Illinois, on November 26 and 27, 1948, with a dinner for the Honor Guest on November 28. Members planning to present papers are reminded that titles and abstracts must be in the hands of the Secretary, Dr. H. M. Briggs, Animal Husbandry Department, Oklahoma A & M College, Stillwater, Oklahoma, by September 10.

Nominations for the 1948 Morrison Award must be in the hands of the Secretary, Dr. H. M. Briggs, by June 15. The rules governing the selection of the winner of this award were published originally in the May 1946 issue of the JOURNAL OF ANIMAL SCIENCE (Vol. 5), pages 236–237. A slightly modified set of rules was mailed to each member of the Society on April 7, 1948. Please note specifically that Rule 14 has been modified to read as follows:

14. All nominations must be accompanied by
    a. A brief biography of the nominee.
    b. A list of publications concerning the research of the nominee.
    c. Copies of the publications concerning the research of the nominee.
    d. A statement of the importance to the livestock industry of the work upon which the nomination is based.

Nominations for the first (1948) American Feed Manufacturers' Association Award must be in the hands of the Secretary, Dr. H. M. Briggs, by June 15. The general terms under which this award will be given were set forth in the February 1948 issue of the JOURNAL OF ANIMAL SCIENCE (Vol. 7), page 143. A complete set of rules was mailed to each member of the Society on April 7, 1948. An award of $1,000 will be made annually during each of three years (1948, 1949, 1950), and, in order that the rules may be available in a more permanent form, they are reproduced below.

Rules Governing the American Feed Manufacturers' Association Awards for Livestock, Dairy Cattle and Poultry Nutrition

The American Feed Manufacturers' Association is presenting three awards of one thousand dollars ($1,000) each annually for a three-year period for work in the field of livestock, dairy cattle and poultry nutrition. One award each is to be presented through the Dairy Science Association, the Poultry Science Association and the American Society of Animal Production.

The purpose of the awards is to stimulate research.

The rules governing awards made through the American Society of Animal Production are as follows:

1. Work must be original in the fields of beef cattle, horse, sheep and swine nutrition. Review articles will not be considered.
2. Research work published in 1946 and 1947 will be considered for the 1948 award; 1947 and 1948 for the 1949 award; and 1948 and 1949 for the 1950 award.
3. Candidates residing in the United States and Canada are eligible. The recipient need not be a member of the American Society of Animal Production.
4. Only research done in public institutions, hospitals and similar organizations will be considered. The award may be made to coworkers, if deemed advisable by the award committee.
5. No individual shall receive the award more than once during the three-year period specified above.
6. No officer or member of the Executive Committee of the American Society of Animal Production or member of committees concerned with the award shall be eligible for the award while holding such position.
7. The selection of the candidate for the award shall be made by a committee of five members of the American Society of Animal Production appointed by the Executive Committee of the Society.

8. The award shall not necessarily be limited to nominees but the nomination of research reports by the membership is invited to minimize possible oversight by the committee of important contributions. Such nominations or citations shall be directed to the Award Committee through the Secretary of the American Society of Animal Production.
9. Prize winners will be awarded the money at the Annual Meeting of the American Society of Animal Production and they will be honored at the regular meeting of the American Feed Manufacturers' Association the following spring. A representative of the American Feed Manufacturers' Association will be present at the annual meeting of the Society when the award is made. The American Feed Manufacturers' Association will present a certificate when honoring the winners.

A second edition of the "American Wool Handbook," by Werner von Bergen and Herbert R. Mauersberger, was issued this year by Textile Book Publishers, Inc., New York 16, N. Y. The format is $5\frac{1}{2}\times7\frac{1}{2}$ inches. The volume contains 1053 pages and has a green cloth cover. The new edition has 24 chapters, one more than the first edition, and 175 additional pages of text. Arthur Besse, President of the National Association of Wool Manufacturers, has again written the foreword to this book and terms it "a most comprehensive study of the wool textile industry with special emphasis on existing American practice." Twenty specialists in various phases of the business collaborated in the preparation of the text, which has been in preparation for over two years. The authors have adhered to the same type of presentation as that used in the first edition. In addition to the thorough treatment of basic material in the book, several flow sheets on yarn manufacture and dyeing and finishing processes have been added in the new edition. Separate chapters have been devoted to the chemical properties and the marketing of wool, the manufacture of carpets and rugs, woven and non-woven felts and a complete bibliography. The labeling act and new tariff schedules are included. Many new photomicrographs, pictures of machinery and other illustrations have been added. Marketing of wool and futures trading in wool and wool tops have been given greater attention than in the first edition. This volume will be of interest to workers in all parts of the world who deal with technical wool problems. The price is $8.00 in the United States and Canada, and $9.00 elsewhere.

A new text entitled "Sheep Science" by W. G. Kammlade was published in 1947 by the J. B. Lippincott Company of Chicago, Philadelphia and New York. The text includes a comprehensive discussion of all aspects of the sheep industry, with a general description of the methods of sheep raising in various parts of the world, descriptions of the more important types of breeds, and discussions of judging, organization of a sheep enterprise, equipment for sheep production, principles of breeding and breeding practices, development of a flock, nutrition and feeding of sheep, economic considerations of the sheep business, selection and purchase of feeder lambs and their management in the feed lot, a detailed discussion of wool and wool terminology, and the various aspects of wool manufacturing, and a chapter on diseases and parasites. Finally there is a discussion of the Western Range area of the United States and of the methods of managing sheep on range lands. This up-to-date text should be of value not only to students and teachers of sheep husbandry, but to all progressive sheep producers. It is one of Lippincott's agricultural science series, contains 534 pages, is well illustrated, and is priced at $5.00.

A meeting of the Western Section of the American Society of Animal Production will be held in Corvallis on June 28, 29 and 30, 1948. Further information may be obtained from Dr. A. W. Oliver, Secretary, Western Section, American Society of Animal Production, at Oregon State College, Corvallis, Oregon.

Leonard H. Blakeslee of the Animal Husbandry Department at Michigan State College has completed the requirements for the Doctor of Philosophy Degree at Cornell University, and has now returned to his regular post in Michigan.

D. M. Seath, formerly of the Dairy Research Department at the Louisiana Agricultural Experiment Station, accepted a position at the University of Kentucky, where he is in charge of the Dairy Section, effective April 20.

A complete and colorful story of the important role played by the sheep industry in building America, is told in "America's Sheep Trails," written by Edward N. Wentworth, and recently published by the Iowa State College Press, Ames, Iowa. The book not only captures the fascination to this phase of agricultural history that other historians have merely touched upon, but also covers a broader range of livestock history than any other single volume yet published. Mr. Wentworth, Director of Armour's Livestock Bureau for more than a quarter of a century, is particularly qualified to tell this story of sheep in America. His work has carried him to almost every livestock-producing area in the country, and he has developed a long and close association with men of the sheep industry. Many of the stories are of personalities he has known, and of the colorful events in which they participated. In addition, Mr. Wentworth has combed all available records of the earlier phases of the industry to make his record complete. The 185 carefully selected photographs, reproductions of paintings, engravings and miniatures, line drawings, maps and letters vividly interpret the text pages. Separate sections deal with specific regions and with specific phases of the sheep industry—for example, *The Merino Wave*, *The Era of the Great Trails*, *The Commercial Feeding Industry*, *Financing the Sheep Business*, *America's Efforts in Sheep Breeding*, *The Cattle-Sheep Wars*, and others. An extensive appendix, biographical sketches, and index are given. The book contains 667 pages and is priced at $7.00.

The Lucas Brothers, Columbia, Missouri, have published a handbook and laboratory manual entitled "The Artificial Insemination of Dairy Cattle," prepared by H. A. Herman and F. W. Madden, both of the Department of Dairy Husbandry, University of Missouri. The volume is designed to serve a useful purpose in bringing together for the student and the field worker the essential facts necessary to carry out the common techniques one must be familiar with to guide successfully the destiny of an artificial breeding program. It contains 20 exercises as follows: Reproductive Organs of the Bull; Reproductive Organs of the Cow; Collection of Semen; Evaluation of Semen—Appearance and Motility; Evaluation of Semen—Concentration of Spermatozoa; Evaluation of Semen—Morphology; Evaluation of Semen—Dead-Alive Staining; Evaluation of Semen—Cold Shock; Evaluation of Semen—Hydrogen-ion Concentration; Evaluation of Semen—Reaction Rates; Evaluation of Semen—Methylene Blue Reduction; Evaluation of Semen—Incubation; Diluters and the Dilution of Semen, and Transporting and Shipping Semen; Insemination of the Cow; Pregnancy Determination; Reproductive Troubles of Dairy Cows; Sire Selection; Bull Management and Care; Organization of Artificial Breeding Associations; Records for Artificial Breeding. References are provided at the end of each exercise to furnish the background of understanding necessary for a scientific approach to these techniques. The manual contains 95 pages and is priced at $3.25.

A book entitled "Management and Feeding of Sheep" by E. T. Baker has been published recently by the Orange Judd Publishing Company, 15 East 26th Street, New York. The price is $3.50, it contains 396 pages, and has a number of illustrations. This book is intended to meet the needs of the farmer, the flock minister and the student of agriculture. It discusses the principles of all important aspects of sheep production and is written in simple style, each subject being taken up in such a fashion that either the practical man or the student can understand both the science and the practice of the subject. Chapter headings include the following: Ancient history, breeds of sheep, structure of the body, functions of the body, the life cycle of sheep, handling sheep, feeding sheep, the farm flock, western range sheep, sheep dogs, the wool industry, medicines used for sheep, poisons affecting sheep, parasites infesting sheep, non-contagious diseases, and infectious diseases.

Robert M. Denhardt is the author of a book entitled "The Horse of the Americas," which was published in 1948 by the University of Oklahoma Press in Norman, Oklahoma. The book contains 286 pages, and is priced at $5.00. It contains a comprehensive account of the arrival, spread and development of the Spanish horse in the New World, beginning with the time that Columbus planted the seed stock in the West Indies, continuing through the period of conquest of both North and South America, and including the development of the cow horse of the late nineteenth century and the modern development of the quarter horse.

It is written in an interesting and informative style, and should be of interest to all students, producers and users of saddle horses. It contains a foreword by J. Frank Dobie.

E. B. Fraser, Assistant Chief in Animal Husbandry at the Central Experiment Station, Ottawa, Canada, recently spent about six weeks with the personnel of the Agricultural Research Center at Beltsville, Maryland, giving particular attention to the swine project.

Dean Colvard has been made head of the Animal Husbandry Department at the North Carolina State College, succeeding J. H. Hilton who was promoted to the positions of Dean of the College and Director of the Experiment Station.

George W. Barnes, for many years extension animal husbandman in the Texas Agricultural Extension Service, has been transferred to the position of District Agent in the same service with headquarters at Ft. Stockton.

Berry N. Duff, extension sheep specialist in the Colorado Extension Service, has been granted temporary leave to serve as acting secretary of the Colorado Wool Growers Association.

R. O. Williams, a graduate of the Clemson Agricultural College, and recently in County Extension work with headquarters at Spartanburg, has been appointed assistant extension animal husbandman in the Georgia Extension Service, and will have headquarters at the Coastal Plains Experiment Station, Tifton, Georgia.

Nels Dahlquist, a graduate of the University of Wyoming and formerly County Agent in Carbon County of that State, was appointed assistant livestock specialist in the Wyoming Extension Service, effective December 1, 1947.

James H. Warner, former county agent, was appointed extension animal husbandman in the Ohio Agricultural Extension Service to succeed L. P. McCann, effective April 1, 1948.

Fordyce Ely, professor of dairy husbandry at the University of Kentucky, has been named Chairman of the Dairy Husbandry Department of the Ohio State University to succeed W. E. Krauss, who became Director of the Ohio Agricultural Experiment Station at Wooster.

The Fifth International Grassland Congress will be held at Noordwijk, Netherlands, June 22 to 26, 1949, and will be followed by a week's excursion covering grassland farming areas in the Netherlands. The program of the Congress will be devoted to technical consideration of grassland problems under conditions comparable to those characterizing Northwestern Europe. Technical papers will be delivered in five Sections: Soil and Manuring, Genetics, Botanical Analysis of Grassland, Establishment, Management, and Utilization of Grassland, and Nutritive Value of Grass and Conservation of Fodder. A few general papers will be presented at plenary sessions. Most papers will be by representatives of various European countries, but Congress officials have invited four papers by men from the United States. Owing to anticipated difficulties in overcoming the effects of World War II on hotel and travel accommodations in the Netherlands, the officials have stated that limitations on attendance at the Congress must be imposed. The United States has been invited to send a small delegation, possibly 12 to 18 members. It is hoped that arrangements for a delegation from this country can be completed before November 1, 1948. The Congress has made no announcement as to whether persons not included in delegations will be permitted to attend. It is assumed, in the absence of such an announcement, that persons other than those designated as members of delegations would have to make their own arrangements with the Congress. The Secretary of the Congress is Dr. C. K. van Daalen, Bilthoven, Netherlands. The Congress fee, including the report of the Congress, will be 40 gilders per person. Hotel accommodations will cost from 9 to 13 gilders a day, and the excursion cost will be about 200 gilders. These costs would be in addition to the costs of transportation to and from the Congress, and subsistence while enroute. Information about the Congress, as received, is being supplied by Mr. P. V. Cardon, Plant Industry Station, Beltsville, Maryland.

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